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# Relationships between Sacred Natural Sites, Ecological Corridors, and Priority Resilience Climate Change Areas in the Upper Paraguay River Basin

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**To my father, Angelo.**
**I am always trying to make you proud.**

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**Summary**

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## General Abstract

This dissertation highlights the critical role of Sacred Natural Sites (SNS) as complementary tools for biodiversity conservation. With the global goal of conserving 30% of terrestrial and aquatic areas by 2030, established by the Kunming-Montreal Global Biodiversity Framework, SNS are proposed as effective measures to be included in Target 3 as Other Effective Area-Based Conservation Measures (OECMs). However, achieving this requires a reassessment, at the national level, of the concept of biodiversity,9’0’ used in decision-making processes for the creation of protected areas. This reassessment must incorporate cultural and spiritual perspectives, as well as the traditional knowledge of Indigenous peoples and local communities, whose practices are deeply intertwined with the conservation of these sacred sites.

We further investigate the spatial relationships of SNS in the Upper Paraguay River Basin, Pantanal - lowland and Cerrado - plateau, focusing on key parameters for biodiversity conservation, such as Ecological Corridors, which is the result of the research carried out for Da Rosa Oliveira (2024) and Priority Resilience Climate Change areas, that were delimited by the research of The Nature Conservancy (2024).

The results reveal a significant overlap between Sacred Natural Sites (SNS) and Ecological Corridors. This highlights their importance in maintaining ecological connectivity and supporting species movement, which directly contributes to increased biodiversity.

It also demonstrates the effectiveness of traditional communities in safeguarding these vital areas, which are also crucial for their well-being, there so, provision of cultural ecosystem services. However, the overlap between SNS and Priority Resilience Climate

Change areas was not statistically significant, likely due to differing selection criteria and the unique characteristics of wetland ecosystems.

Despite this, our findings emphasize the essential role of SNS in preserving biodiversity and cultural heritage, particularly in regions of high biological and cultural diversity like the Pantanal. By integrating SNS into conservation strategies, this study reinforces their value as a complementary approach to achieving global biodiversity targets and ensuring the resilience of both ecosystems and traditional communities.

## Resumo Geral

Esta dissertação destaca o papel crucial dos Sítios Naturais Sagrados (SNS) como ferramentas complementares para a conservação da biodiversidade. Com a meta global de proteger 30% das áreas terrestres e aquáticas até 2030, estabelecida pelo Marco Global de Biodiversidade de Kunming-Montreal, os SNS são propostos como medidas eficazes a serem incluídas no Target 3, como Outras Medidas de Conservação Baseadas em Áreas (OECMs). No entanto, para que isso seja alcançado, é necessário reavaliar, em nível nacional, o conceito de biodiversidade utilizado nos processos de tomada de decisão para a criação de áreas protegidas, que deve incorporar perspectivas culturais e espirituais, bem como o conhecimento tradicional de povos indígenas e comunidades locais, cujas práticas estão profundamente ligadas à conservação desses sítios sagrados.

O estudo também investiga as relações espaciais dos SNS no Pantanal e no planalto da Bacia do Alto Paraguai (BAP), com foco em parâmetros-chave para a conservação da biodiversidade, como Corredores Ecológicos, que é o resultado da pesquisa realizada Por Da Rosa Oliveira (2024) e Áreas Prioriárias Resilientes às Mudanças Climáticas, que foramdelimitadas pela pesquisa da The Nature Conservancy (2024).

Os resultados revelam que os SNS estão significativamente associados aos Corredores Ecológicos, destacando sua importância na manutenção da conectividade ecológica e no suporte ao movimento das espécies. No entanto, a sobreposição entre os SNS e as Áreas Prioritárias de Resiliência Climática não foi estatisticamente significativa, possivelmente devido a critérios de seleção distintos e às características únicas dos ecossistemas de áreas úmidas. Apesar disso, os achados reforçam o papel essencial dos SNS na preservação da biodiversidade e do patrimônio cultural, especialmente em regiões de alta diversidade biológica e cultural, como o Pantanal. Ao integrar os SNS nas estratégias de conservação, essas áreas são uma abordagem complementar para alcançar as metas globais de biodiversidade e garantir a resiliência de ecossistemas e comunidades tradicionais.

## Popular Abstract

This study shows how Sacred Natural Sites (SNS) can help protect nature and biodiversity. With the global goal of conserving 30% of land, water, and seas by 2030, SNS are presented as a complementary solution to achieve this target. These sites, which hold great cultural and spiritual importance, are also essential for preserving biodiversity. However, for SNS to be officially recognized as a conservation area, it is necessary to rethink, at the national level, the concept of biodiversity used in decisions about protected areas, including the knowledge and traditions of Indigenous peoples and local communities.

The study analyzed SNS in the Upper Paraguay River Basin, Pantanal - lowland e Cerrado - plateau, focusing on their relationship with Ecological Corridors (areas that connect habitats and help species move) and Priority Resilience Climate Change areas (places important for adapting to climate change). The results show that SNS are strongly linked to Ecological Corridors, helping to maintain connections between habitats.

However, the relationship with Priority Resilience Climate Change areas was less evident, likely due to the unique characteristics of wetland ecosystems. Even so, the study highlights that SNS are essential for protecting biodiversity and cultural heritage, especially in rich regions like the Pantanal. By including SNS in conservation strategies, we can ensure the protection of nature and traditional communities.

## Resumo Popular

Este trabalho mostra como os Sítios Naturais Sagrados (SNS) podem ajudar a proteger a natureza e a biodiversidade. Com a meta global de conservar 30% das terras, águas e mares até 2030, os SNS são apresentados como uma solução complementar para alcançar esse objetivo. Esses locais, que têm grande importância cultural e espiritual, também são fundamentais para a preservação da biodiversidade.

No entanto, para que os SNS sejam reconhecidos como áreas de conservação, é necessário repensar, no Brasil, o conceito de biodiversidade usado nas decisões sobre áreas protegidas, incluindo os conhecimentos e as tradições dos povos indígenas e comunidades locais.

O estudo analisou os SNS no Pantanal e na Bacia do Alto Paraguai, avaliando sua relação com Corredores Ecológicos (áreas que conectam habitats e ajudam no movimento das espécies) e Áreas Prioritárias de Resiliência Climática (locais importantes para enfrentar as mudanças climáticas). Os resultados mostram que os SNS estão fortemente ligados aos Corredores Ecológicos, ajudando a manter a conexão entre os habitats. Já a relação com as Áreas de Resiliência Climática não foi tão evidente, possivelmente por causa das características únicas das áreas úmidas.

Mesmo assim, o estudo reforça que os SNS são essenciais para proteger a biodiversidade e o patrimônio cultural, especialmente em regiões ricas como o Pantanal. Ao incluir os SNS nas estratégias de conservação, podemos garantir a proteção da natureza e das comunidades tradicionais.

## General Introduction

The study of Sacred Natural Sites (SNS), defined by Wild & McLeod (2008) as "areas of land or water having special spiritual significance for people and communities", has gained increasing attention due to their cultural, spiritual, and ecological significance. This relevance has been further emphasized in global conservation agendas, such as the Kunming-Montreal Global Biodiversity Framework adopted during COP15 (CBD/COP/DEC/15/4), where this framework underscores the importance of integrating diverse knowledge systems, including those of Indigenous and traditional populations, into biodiversity conservation strategies. One example of this integration is through Other Effective Area-Based Conservation Measures (OECMs), Target 3, which recognizes the value of areas conserved by local communities and their traditional practices. The emphasis on OECMs at COP15 highlights the growing recognition of SNS as a vital components of global conservation efforts.

However, as highlighted by Sullivan et al. (2024), there is a notable regional bias in the existing literature. Most studies focus on Asia, Africa, and Europe, while the Americas, particularly the Global South, remain underrepresented. This gap underscores the need for more research in these regions to better understand the role of SNS in biodiversity conservation and cultural heritage preservation.

This dissertation addresses these gaps by discussing the importance of valuing the worldviews of Indigenous and traditional populations. It proposes, at the national level, a new way to evaluate biodiversity that transcends the predominantly Western perspective. By incorporating alternative understandings of biodiversity—drawing on the strengths of Western approaches while embracing the cosmovision and knowledge systems of traditional communities—the study shows the importance of validating Sacred Natural Sites as effective conservation tools.

The research also examines the spatial overlap between SNS, Ecological Corridors, and Priority Resilience Climate Change areas in the Upper Paraguay River Basin, Pantanal - lowland e Cerrado - plateau. This analysis provides a comprehensive understanding of the role of SNS in biodiversity conservation and climate resilience, offering insights into how these sacred sites can contribute to broader conservation strategies.

The dissertation is structured into two interconnected chapters, each addressing key aspects of Sacred Natural Sites (SNS) and their role in biodiversity conservation.
Chapter 1: This chapter is based on an article submitted to *Ethnobiology and Conservation* as a Policy Brief, where we discuss the contemporary and highly relevant concept of Other Effective Area-Based Conservation Measures (OECMs).

We propose Sacred Natural Sites as an effective form of conservation, arguing that the current concept of biodiversity, as defined by the Convention on Biological Diversity (CBD), is limited. The CBD's definition reflects a predominantly Western perspective: "variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." We suggest that this definition could be expanded, at least at the national level, to incorporate alternative understandings of biodiversity, such as the worldviews of traditional and Indigenous peoples. This expansion would validate Sacred Natural Sites (SNS) as effective conservation tools and integrate them into broader conservation strategies.

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Chapter 2: This chapter represents the core of the research project. It examines the spatial congruence between SNS, Priority Resilience Climate Change areas, and priority conservation areas such as Ecological Corridors. The primary objective is to determine whether SNS are relevant to biodiversity conservation in the Upper Paraguay River Basin - Pantanal Lowland e Cerrado plateau. The study includes detailed methodologies and analyses related to ecological corridors and priority areas for climate resilience, providing a comprehensive understanding of the role of SNS in these critical conservation contexts.

# Chapter 1

# Sacred Natural Sites as Other Effective Area-Based Conservation Measures: Embracing an Inclusive and Plural Perspective on the Meaning of Biodiversity

## Abstract

Sacred Nature Sites (SNS) hold significant potential as effective measures for biodiversity conservation. The target 3 of the Convention on Biological Diversity (CBD) to conserve 30% of land, waters and seas by 2030, there is a growing recognition of the need for complementary conservation efforts like SNS. These sites, rich in biological and cultural diversity, offer an alternative and complementary means of safeguarding areas driven by community will. This concept aligns with the principles of Other Effective Area-Based Conservation Measures (OECMs) or Additional Conservation Areas (ACAS). We call attention to the challenges of comprehensively including SNS as OECMs. Ideally, we believe that the CBD's concept of biodiversity should be revised to better reflect the varying interpretations of biodiversity across different cosmological classification systems. However, in practical terms, it is unlikely that there will be an administrative opportunity for such a change in the coming years. Therefore, as a pragmatic approach, we propose that these diverse perspectives on biodiversity be incorporated into national-level reports and applied to site-specific monitoring approaches, particularly in sacred sites. This approach could enhance more plural and enriched biodiversity complementary indicators as defined in the Kunming-Montreal Global Biodiversity Framework's documents (e.g. (CBD/SBSTTA/26/INF/14), thereby aligning and ensuring the inclusion of diverse knowledge systems and visions of monitoring OECMs.

**Keywords:** Protected Areas; Cosmologies; Traditional knowledge.

## Resumo

Os Sítios Sagrados da Natureza (SNS) possuem um potencial significativo como medidas eficazes para a conservação da biodiversidade. A Meta 3 da Convenção sobre Diversidade Biológica (CDB) estabelece a conservação de 30% das terras, águas e mares até 2030, aumentando o reconhecimento da necessidade de esforços complementares de conservação, como os SNS. Esses locais, ricos em diversidade biológica e cultural, oferecem um meio alternativo e complementar de proteção de áreas, impulsionado pela vontade das comunidades. Esse conceito está alinhado aos princípios das Outras Medidas Efetivas de Conservação Baseadas em Área (OECMs) ou Áreas de Conservação Adicionais (ACAs). Chamamos a atenção para os desafios de incluir de maneira abrangente os SNS como OECMs. Acreditamos que o conceito de biodiversidade da CDB deveria ser revisado para refletir melhor as diferentes interpretações de biodiversidade nos diversos sistemas de classificação cosmológica. No entanto, na prática, é improvável que haja uma oportunidade administrativa para tal mudança nos próximos anos.

Portanto, como abordagem pragmática, propomos que essas diversas perspectivas sobre biodiversidade sejam incorporadas nos relatórios nacionais e aplicadas a abordagens de monitoramento específicas para cada local, especialmente nos sítios sagrados. Essa estratégia poderia fortalecer indicadores complementares de biodiversidade mais plurais e enriquecidos, conforme definido nos documentos do Marco Global de Biodiversidade Kunming-Montreal (por exemplo, CBD/SBSTTA/26/INF/14), garantindo a inclusão de diversos sistemas de conhecimento e visões no monitoramento das OECMs.

**Palavras-chave:** Áreas Protegidas; Cosmologias; Conhecimento Tradicional.

## Introduction

Alarming rates of biodiversity loss (Díaz 2019) emphasize the urgency of increasing global conservation efforts (Mace et al. 2018). Recently, the Convention on Biological Diversity (CBD) established in Target 3, that at least 30 percent of terrestrial and inland water areas, and marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed by 2030 to tackle the biodiversity crisis (CBD/COP/DEC/15/4). While Protected Areas (PAs) have historically been considered the cornerstone action of biodiversity conservation, concerns are now emerging regarding their effectiveness in successfully protecting nature and guaranteeing people's well-being, partially because many protected areas seem not to be effectively managed (Laurance et al. 2012; Watson et al. 2014).

Biodiversity conservation can be effectively achieved through three types of conserved areas: Protected Areas (PAs), Additional Conservation Areas (ACAs) or Other Effective Area-Based Conservation Measures (OECMs) (to maintain consistency throughout our text, we adhered to the OECMs term stated by the CBD - that is “a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio-economic, and other locally relevant values” (CBD/COP/DEC/14/8); and Indigenous peoples and local communities (See Salafsky et al. 2024). Sacred Natural Sites can overlap with any of these types. Among the possible solutions to conservation, stands out Sacred Nature Sites (SNS), defined as “areas of land or water having special spiritual significance for people and communities” (Wild and McLeod 2008). Recognizing the cultural and spiritual significance of SNS for various stakeholder groups could present an opportunity to enhance conservation practices (Mikusiński et al. 2014) and recognize local knowledge.

These sites have a long history as the oldest form of ecosystem and habitat protection in human civilization (Dudley et al. 2009). They encompass various natural features such as single trees, rock outcrops, rivers, mountains, wetlands, and islands (Dudley et al. 2005) and also include built features such as temples or monasteries (Dudley et al. 2009; Frascaroli et al. 2016), they hold special values for different social groups, traditions, beliefs, and cultural values, satisfying humanity's quest for something meaningful and establish a strong connection with the environment (Putney 2005). Numerous examples of SNS around the world demonstrate the link between sacred sites and conservation. In India, the Western Ghats (Figure 1) and the Himalayas are home to numerous sacred sites that not only play a crucial role in safeguarding biodiversity but also serve as a vital connection between culture and spirituality (Rath and Ormsby 2020). Similarly, the tribal communities have a rich knowledge of local flora and fauna, which they classify based on their uses, habitats, and other characteristics (Trujillo et al. 2018). This traditional knowledge passed down through generations, plays a crucial role in biodiversity conservation (Faizi and Nair 2016). The Indigenous traditionally important inland wetlands are home to many national endemics and traditionally important plants in Fiji. The Tagimoucia Lake of Taveuni island (Figure 1) is part of the Taveuni Forest Reserve and is home to Fiji’s rare and island endemic flower Medinilla *Waterhousei Sem* (Ellison 2009, figure 1). The Floating Island Lake system of the Nadogo community of the Vanua Levu Island is an ecosystem hotspot for the endemic damselfly *Pseudagrion pacificum* (Rashni et al. 2023). The ‘Navakasobu villages’ Kuta reed (*Eleocharis dulcis*) freshwater swamp of Vanua Levu Island is a socio-ecological conservation stronghold for traditional kuta mat design clans for the Macuata province of Fiji (Ghazanfar 2001) and the largest standing ecosystem/habitat for the only endemic sub-specie dragonfly of Fiji - *Rhyothemis phyllis* (Brauer 1867; Rashni et al. 2023).

**Figure 1**. Examples of Sacred Natural Sites. From left to the right: **1(a/b).** The mountain chain of the Western Ghats in India represents geomorphic features of immense importance with unique biophysical and ecological processes. The site's high montane forest ecosystems influence the Indian monsoon weather pattern with an exceptionally high level of biological diversity and endemism. This mountain chain is recognized as one of the world's eight 'hottest hotspots' of biological diversity along with Sri Lanka (Source: Unesco - World Heritage Convention). **1a:** Grass Hills view from Akkamalai (Photo Credit: S. Thangaraj Panner Selvam, Forest Ranger, Ulandy Range, Topslip). **1b:** Karajavade Valley - Koyana Sanctuary (Photo Credit: G. Sai Prakash). **1c:** Lake Tagimoucia an old volcanic crater in the mountains that rise above Somosomo and Naqara in Fiji (Source: The University of South Pacific). **1d:** The tapioca is Fiji's endemic and elusive national flower, at the Taveuni at the Taveuni Forest Reserve (Photo Credit **1c** e **1d:** John Game).

There are different specific reasons for natural sites to be considered sacred and correspondingly, many, different management strategies and governance arrangements are used for these sites (Tatay and Merino 2023). However, a common feature of these sites is that due to the presence of long-term customary regulations on the use and access to resources, and sometimes different uses, they frequently host higher biodiversity values than neighboring areas while also supporting people's cultural values (Verschuuren et al. 2007). SNS offers an alternative means of safeguarding important areas for conservation driven not necessarily by state control, but rather by people's cultural values and it is a way to integrate conservation with faith or spirituality (Mikusiński 2014). SNS possesses all the attributes needed for incorporation into these other areas, although significant challenges remain for the comprehensive inclusion of sacred sites as OECMs (Maxwell 2020; Gurney et al. 2023; Hoffmann 2022). Moreover, although the recent discourse of global institutions around biodiversity increasingly incorporates indigenous knowledge, sacred sites, and cultural values, many conceptual and operational issues remain open.

*Operational and conceptual challenges*

Recently, Gurney et al. (2023) proposed three important directions to guide progress in Other Effective Area-Based Conservation Measures (OECMs) under the Convention on Biological Diversity (CBD) targets for 2030-2050: (1) adopting a diverse toolbox of area-based conservation approaches to halt biodiversity loss, (2) centering social equity in area-based conservation efforts, and (3) implementing robust monitoring and review mechanisms to ensure effective and equitable outcomes. We recognize that the CBD has made significant conceptual and practical advances in these areas, particularly in integrating social and pluralistic dimensions into the Kunming-Montreal Global Biodiversity Framework’s documents. However, we argue that it is crucial to clarify the concept of biodiversity that underpins the CBD's goals and reporting frameworks for 2030 and 2050. The current definition adopted by the CBD (Article 2, Use of terms) is rooted in a predominantly Western perspective: “the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (CBD 1992).” While valuable, this definition separates people from nature, overlooking relational and Indigenous perspectives that view people and their reciprocal relationships with lands and seas as indivisible entities. These relational values comprise more profound associations such as how nature shapes a person or people's place-based identity, social relations, or culture (Ishihara 2018; Kleespies and Dierkes 2020). Importantly, this limited Western perspective is currently challenged by a strong global momentum towards embracing pluralistic values of nature, partially claimed by indigenous and local communities (e.g. ICCA Consortium) participation in the international debates. Nonetheless, questions about how pluralistic values are expected to be incorporated remain. Adopting such pluralism is necessary not only for the sake of equity and justice but also for taking advantage of multiple ways of knowing how to improve conservation outcomes. The CBD definition of biodiversity based on Western ways of knowing might often be inadequate for capturing useful information without traditional knowledge. For example, the Martu people of Western Australia have five different names for patches of Spinifex grasslands for each successional stage after fire, based on a classification system that serves to create niches for native biodiversity and facilitate the ecological role of predator species that are themselves functionally vital (Bird et al. 2018). In this example, Indigenous knowledge specifies the appropriate spatial extent and temporal grain in which the Western definitions of biodiversity can be used to demonstrate the biodiversity benefits of Aboriginal cultural burning. Here fire is used to optimize nature's contributions to people (Díaz et al. 2018) and as people's contribution to nature under the caring for country approach (Larson et al. 2023) which does not have any explicit connection to the CBD definition of biodiversity.

In synthesis, ideally, we believe that the CBD's concept of biodiversity should be revised to better reflect the varying interpretations of biodiversity across different cosmological systems of classification. However, in practical terms, it is unlikely that there will be an administrative opportunity for such a change in the coming years. Therefore, as a pragmatic approach, we propose that these diverse perspectives on biodiversity be incorporated into national-level reports and applied to site-specific approaches, particularly in sacred sites.

As previously mentioned, if biodiversity conservation mainly occurs through Protected Areas (PAs) and within the IUCN concept of PAs, which is globally employed as a framework for categorizing protected areas, it emphasizes that PAs "must ensure the protection and maintenance of biological diversity, as well as natural and associated cultural resources, and be managed through legal or other effective means",  it is necessary to expand the understanding of what their culture is and how much biodiversity is intrinsic to it. A recent example, in 2023 the Colombian government in agreement with Indigenous communities Arhuaco, Kogui, Wiwa y Kankuamo from the Sierra Nevada de Santa Marta extended part of the national park up to the black line, a protected barrier that aims is safeguard cultural values and biodiversity (MADS, Resolution 13). Thus, building local knowledge and belief systems is of vital importance for the success of participatory ecosystem management and best practice in biodiversity conservation (McNeely 2005; Shepherd 2004).

In fact, biodiversity for many communities includes sacred entities, transmutation among organisms, and other aspects. A compelling illustration of this phenomenon can be observed in the forest health monitoring methodologies developed by the Guarani Kaiowá Indigenous community in Brazil. These methodologies transcend the conventional taxonomic structures of Western science, incorporating a holistic perspective that recognizes and integrates spiritual entities inherent in their cosmologies. Within the framework of the Guarani Kaiowá worldview, biodiversity surpasses the realm of observable flora and fauna, encompassing a spectrum of sacred beings and metaphysical phenomena interwoven with the natural environment (Ioris 2020). By assimilating these spiritual dimensions into their monitoring practices, the Guarani Kaiowá not only enhance their conservation endeavors but also establish a profound connection between their cultural heritage and the conservation of biodiversity (Ioris 2020). Moreover, some communities have their ways of classifying and valorising ecosystems, such as Afro communities in Brazil, who understand landmarks as homes of their gods, such as the ‘Pedra do Xangô’ in the Bahia State. Many Indigenous communities in India maintain their sacred groves, each known by a unique name that reflects the geographical location and its associated deities or demons, or ancestors. For instance, these groves are referred to as 'kovil kaadugal' in Tamil Nadu, 'Ambalakaavu' or 'Serpakaavu' in Kerala, 'Devarbana' in Karnataka, and 'Oran' in Rajasthan (Gunasekaran 2007). Similarly, native fijian 'ITaukei' communities have their own traditions, such as ancestor-gods 'The Kalou-Vu' of the Indigenous land or 'Vanua' that are spiritual guardians (Thomson 1895).

*Making the definition of biodiversity more inclusive*

Thus, to develop inclusive monitoring and avoid colonial views on what biodiversity means, we are calling attention to the need for a more inclusive definition of biodiversity, particularly in the national context of OECMs site-level monitoring approaches, particularly in sacred areas, including different cosmological systems of classification and meanings. We are not advocating for completely overhauling existing biomonitoring systems based on the current biodiversity concept of CBD to include a more completely local communities view approach on biodiversity meanings in sacred territories, but rather suggesting that to truly include different cosmologies, it's necessary to build a more plural and enriched picture of biodiversity indicators, including those valid for local communities considering their own cosmologies. In practical terms, following the Kunming- Montreal Global Biodiversity Framework (CBD/SBSTTA/26/INF/14), countries can include such indicators as complementary indicators. This process should be undertaken through consultation and collaborative learning with these Indigenous people and local communities, as there is evidence that involvement of Indigenous communities in Protected Area management can increase management effectiveness in these areas (Austin 2018). This can be achieved without juxtaposing Western Science against traditional ecological knowledge and Indigenous values, for example through the practice of "two-eyed seeing" i.e. learning to see from one eye with the strengths of Indigenous knowledge and ways of knowing, and from the other eye with the strengths of Western knowledge and ways of knowing, and to using both these eyes together, for the benefit of all (Bartlett et al.

2012). In this way, we believe that the CBD can take an important step to align and ensure the inclusion of diverse knowledge systems to the concept of biodiversity and visions of monitoring OECMs.

# Chapter 2

# Spatial Relationship between Sacred Natural Sites, Ecological Corridors, and Priority Climate Change Resilience areas in Upper Paraguay River Basin: implications for conservation planning

## Abstract

Protected Areas (PAs) face growing challenges, especially due to climate change and landscape changes, prompting complementary conservation approaches like Sacred Natural Sites (SNS). SNS, recognized for their cultural and spiritual significance, often harbour rich biodiversity and provide crucial ecosystem services. This study investigates SNS's distribution and conservation value in the Upper Paraguay River Basin (UPRB) in Brazil, a region with high biological diversity that includes the Pantanal lowland and the Cerrado plateu. Building on the understanding that landscape attributes may influence cultural practices and biodiversity, we analyzed the spatial congruence between SNS and priority conservation areas, particularly those resilient to climate change and ecological corridors. The results showed a higher percentage of Ecological Corridors associated with Sacred Natural Sites than with areas considered non-sacred. However, for Priority Resilience Climate Change areas, there is no difference between SNS and random areas. The findings also emphasize the importance of traditional and Indigenous communities, whose knowledge and cultural practices are fundamental to the maintenance and conservation of these Sacred Sites. Ecological Corridors are  key areas, often used as references for conservation decisions, further highlighting the important role of Sacred Natural Sites in preserving the Upper Paraguay River Basin.

**Keywords:** Protected Areas; Cosmologies; Traditional knowledge.

## Resumo

As Áreas Protegidas (APs) enfrentam desafios crescentes, especialmente devido às mudanças climáticas e transformações na paisagem, o que exige abordagens complementares de conservação, como os Sítios Naturais Sagrados (SNS). Os SNS, reconhecidos por sua importância cultural e espiritual, frequentemente abrigam rica biodiversidade e fornecem serviços ecossistêmicos cruciais. Este estudo investiga a distribuição e a importância da conservação dos SNS na Bacia do Alto Paraguai (BAP), no Brasil, uma região de alta diversidade biológica que inclui o Pantanal e o Cerrado. Partindo do entendimento de que os atributos da paisagem podem influenciar tanto as práticas culturais quanto a biodiversidade, analisamos a congruência espacial entre os SNS e áreas prioritárias para conservação, particularmente aquelas resilientes às mudanças climáticas e os corredores ecológicos. Os resultados mostraram uma maior porcentagem de Corredores Ecológicos associados aos Sítios Naturais Sagrados em comparação com áreas não sagradas. No entanto, para as áreas prioritárias de resiliência climática, não existe diferença entre as áreas. Os achados também destacam a importância das comunidades tradicionais e indígenas, cujos conhecimentos e práticas culturais são fundamentais para a manutenção e conservação desses Sítios Sagrados. Os Corredores Ecológicos são áreas muito importantes, frequentemente usadas como referência para decisões de conservação, reforçando ainda mais o papel relevante dos Sítios Naturais Sagrados na preservação do Pantanal e da Bacia do Alto Paraguai.

**Palavras-chave**: Áreas Protegidas; Cosmologias; Conhecimento Tradicional.

## Introduction

*Sacred Nature Sites in the context of biodiversity and climate change agendas*

In the 19th century, the Western concept of Protected Areas (PAs) emerged in response to the growing recognition of the impacts of the industrial revolution (Gurney et al. 2023). Initially, the main objective was to preserve places with iconic landscapes or wildlife. Currently, climate change is drastically altering the landscape of protected areas, threatening biodiversity, and ecosystems through fluctuating temperatures, shifting precipitation patterns, and other climatic effects (Upadhyay 2020). While PAs are the frontline of biodiversity conservation and the foundation of modern conservation approaches (Wu et al. 2023), there is now a growing need to expand the PAs network to adapt these areas to play an effective role in conserving biodiversity, achieving nature-based climate change solutions (Griscom et al. 2017, Dobrowski et al. 2021) and supporting indigenous and traditional communities that depend on these ecosystems for their livelihoods and face even greater challenges due to climate change. So, there is a crescent need for promoting synergies between the climate change and biodiversity agendas worldwide.

As awareness grows that Protected Areas alone are insufficient to address the conservation crisis possible solutions are appearing to conservation like Sacred Nature Sites (SNS). It can be defined as "areas of land or water having special spiritual significance for people and communities" (Wild & McLeod 2008). These sites hold cultural and spiritual importance for indigenous and local communities, often embodying traditional knowledge and biodiversity hotspots (Verschuuren 2021). The SNS encompass a variety of natural and built features, from singles trees to rock outcrops, rivers, mountains, islands (Dudley et al. 2005) and could consist in built features for example temples or monasteries (Dudley et al. 2009, Frascaroli et al. 2016). These sites hold profound value for different social groups, traditions, beliefs, and cultural values, satisfying humanity's quest for meaning and establishing a connection with the environment (Putney 2005). These relational values comprise more profound associations such as how nature shapes a person or peoples' place-based identity, social relations, or culture (Ishihara 2018, Kleespies & Dierkes, 2020).

Beyond their cultural importance, SNS also play a fundamental role in uniting biological and cultural aspects regarding biodiversity conservation. Numerous examples worldwide, including forest patches conserved around places of worship (Bhagwat & Rutte 2006) demonstrate this link, for example, the Yosemite National Park, one of the oldest modern PA, which is considered sacred and protect by local people for many centuries (Dudley et al. 2005). In addition to their cultural significance, these geographically dispersed sacred natural sites often serve as vital refugia for plant and animal species (Mgumia & Oba 2003), contributing to water filtration, soil erosion reduction, and a range of other ecosystem services and functions that support life both within and beyond their boundaries (Bodin et al. 2006).

Some of these sites may even represent the last remaining habitats for endemic, threatened, rare, or specialist species (Zannini et al. 2021). In Tanzania there are over 600 sacred groves, in Ghana over 2,000 sacred forests, in India over 100,000. In Kenya, the Kaya Forest, part of coastal forests that extend from Zanzibar, name as Zanzibar-Inhambane lowland Mosaic (Burgess & Clarke 2000, Kibet & Nyamweru 2008, Nyamweru 1996), are sacred among the Mijikenda people, found on the Kenyan Coast. The forest region is rich in species level exhibits a rare biodiversity (Kihonge 2017). Sacred Natural Sites unite biological and cultural diversity, fostering "people-inclusive" management and providing opportunities for environmental education, cross-cultural learning, and knowledge transmission (Verschuuren et al. 2007). Nonetheless, the predominant focus of research on sacred natural sites has been on Asia and Africa (Dudley et al. 2010). The evidence supporting the positive impact of SNS on biodiversity conservation is strong, although more research is needed to fully understand their potential in tropical regions (Zannini et al. 2021).

In the face of the accelerated rate of biodiversity loss (Díaz 2019) and the growing advocacy for conservation efforts worldwide (Mace et al. 2018), a new complementary conservation policy tool emerges. The Other Effective Area-based Conservation Measures (OECMs), means “a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values (CBD/COP/DEC/14/8). This approach is set to massively accelerate, with almost 200 countries recently committing to ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, under the United Nations (UN) Convention on Biological Diversity’s (CBD) Kunming-Montreal Global Biodiversity Framework (CBD/COP/DEC/15/4). While some view this target as ambitious, it reveals the urgency to identify efficient conservation tools and prioritize areas based on various biological mechanisms (Gurney et al. 2023).

Moreover, it is very relevant to consider the role of Protected Areas (PAs) and Sacred Natural Sites (SNS) in climate change mitigation and adaptation, particularly in the context of vulnerable species and communities (Marselle et al 2019). Identifying places with the potential to sustain biodiversity and people in the face of these changes is essential for planning effective conservation and restoration actions (TNC 2024). Therefore, investigating the potential overlap between Sacred Natural Sites (SNS) and resilient areas considering connectivity for biodiversity could offer further advantages for both environmental protection and human well-being. Consequently, the incorporation of SNS as other effective area-based conservation measures (OECMs) into conservation strategies is becoming increasingly important in guaranteeing the resilience of both nature and vulnerable communities in the face of environmental challenges.

In summary, throughout history, the agendas of nature conservation, climate change mitigation, promotion of cultural diversity, and achievement of the Sustainable Development Goals (SDGs) have progressed in parallel. However, there is an increasingly recognized need to integrate these agendas to address emerging environmental and social challenges, underscoring the importance of incorporating measures such as Sacred Natural Sites (SNS) and other effective conservation areas (OECMs) into biodiversity conservation and climate change adaptation strategy.

*Sacred Natural Sites in Brazil*

In Brazil, a bibliographic survey, carried out in 2015 (Fernandes-Pinto 2017), identified 60 places considered SNS, according to the definition proposed by Wild e McLeod (2008), distributed across 14 Brazilian states. Fernandes-Pinto (2017) is working on mapping all the SNS in Brazil through bibliographical surveys and citizen science as we can see at her website: https://sitiosnaturaissagrados.org/sobre-erika-fernandes-pinto/. Despite the potential of the Brazilian territory for the presence of SNS, national insertion on the world stage is still scarce, despite several international initiatives in recent years (Fernandes-Pinto 2017, Sullivan et al 2024). Many places considered SNS are associated with protected areas legally established by public authorities therefore PAs are the main strategy to achieve conservation.

These include Conservation Units, which are public spaces categorized into Sustainable Use or Full Protection, according to the Brazilian Nacional Protected Areas System Law (SNUC 2000) classification. Moreover, within private properties, there exist certain areas designated as Permanent Protected Areas due to their ecological fragility and the vital ecosystem services they provide. Additionally, there are areas designated as Legal Reserves, wherein the size is determined as a percentage of the property with the aim of promoting biodiversity conservation. Despite this, only 19% of Brazil´s continental territory is occupying as protected areas (MMA 2022).

One of the most important biodiversity and ecological service areas in the world and one of the largest wetlands occupying 179,300 km² in Brazil (Costanza et al. 1997, Tortato & Izzo 2017, Tomas et al. 2019), the Pantanal provides critical ecosystem services such as biodiversity conservation, food, freshwater, climate stability, and flood control (Bolzan et al. 2022). These services are not only essential for ecological balance but also contribute significantly to human well-being, as they support livelihoods, cultural identity, and mental health (Bolzan et al. 2022). The Pantanal has only 5.71% of its area protected as Units of Conservation (Tomas et al. 2019). It is part of the Upper Paraguay River Basin (UPRB), together with the plateau, a different ecosystem – Cerrado - where there are important sites related to religiousness and spirituality, such as Christianity, Buddhism, Afro-religions (e.g., Candomblé), Indigenous Traditions, Spiritualism, and Mysticism (Wantzen et al. 2023). These areas are poorly studied, mapped, and documented.

This raises concerns because spiritual well-being is increasingly considered an important dimension of human health (Marselle et al. 2019), and sacred areas seem to be important for biodiversity conservation and ecological services (Dudley et al. 2009, Fernandes-Pinto 2017). Moreover, the Pantanal's cultural richness, shaped by Indigenous populations and traditional communities, highlights the need to integrate cultural services into conservation strategies. The monetary valuation of ecosystem services in the Pantanal, estimated at billions of dollars annually, further underscores the importance of preserving these areas for both ecological and human well-being (Dudley et al. 2009, Fernandes-Pinto 2017, Bolzan et al. 2022).

By analyzing the distribution and significance of Sacred Natural Sites (SNS) for biodiversity conservation in the UPRB through the correlation and overlap between SNS and different facets of biodiversity as also ecosystem services, we can establish a path to improve the use and conservation of SNS areas, expanding conservation efforts. Building on the concept that geomorphology influences both cultural aspects and biodiversity (Burnside et al. 2012), we investigated the spatial overlap between SNS and priority conservation areas, including Priority Resilient Climate Change areas and connectivity through Ecological Corridors. Our approach has the potential to integrate conservation practices with cultural diversity. We expected significant spatial congruence between SNS and Priority Resilient Climate Change areas, as these regions could serve as refuges for species and landmarks for humans and thus were likely important for cultural and spiritual activities in the past. Given that Ecological Corridors can connect fragmented landscapes, facilitating species movement, and also serve scenic, cultural, social, and recreational purposes for people, we also expect a significant overlap between sacred areas and Ecological Corridors in the Upper Paraguay River Basin.

## Methods

*Study Area*

The Upper Paraguay River Basin (UPRB) is in the central region of South America, covering the territories of Brazil, Bolivia, and Paraguay. It has an area of approximately 600,000 km², is responsible for a significant portion of the continent's drainage (Tomas et al. 2019). The UPRB in Brazil, the focus of the study, is formed by the lowland (Pantanal) and plateau (Cerrado e Amazon ecosystems). In this study, the research was focused in the Pantanal e Cerrado (Figure 1). The Pantanal Plain covers an area of approximately 150,000 km² (Padovani 2010), characterized by a low slope and a mosaic with diverse types of vegetation (Pott 2009, Pott et al. 2014). The main rivers and springs drain the lowland originating in the plateau, resulting in two areas with great functional and ecological interdependence, but belonging to two different ecosystems (Roque et al. 2016).

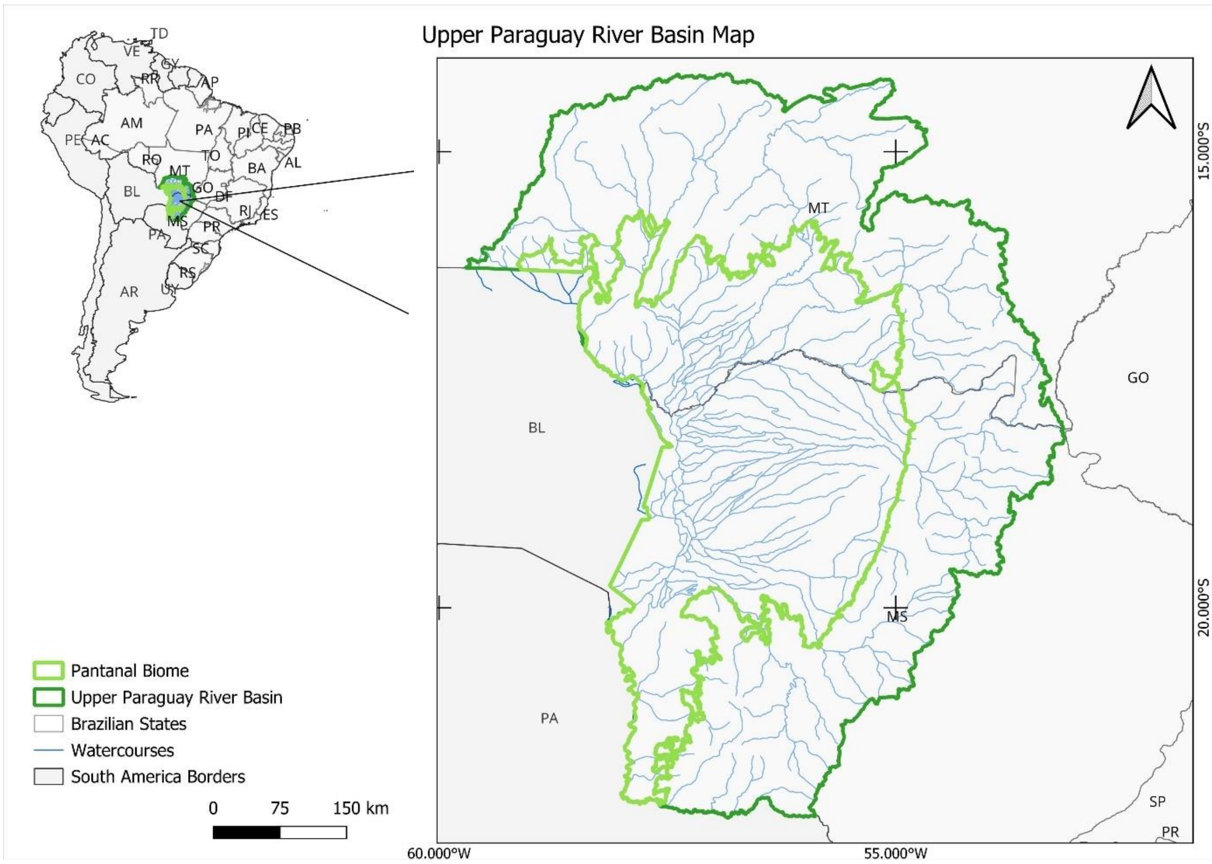


**Figure 1:** Upper Paraguay River Basin, the Cerrado plateau, and the lowland (floodplain), Pantanal, highlighted. (Fonte: ANA).

The region underwent a major intensification of land use over the last 30 years, mainly in the plateau, which in 2016 had 61% of the land as anthropogenic use, against 13% in the lowlands (Roque et al. 2016). The Pantanal has a highly diversified fauna and flora, including iconic species such as jaguars, tapirs, caimans, and macaws (Tortato & Izzo 2017, Tomas et al. 2019). Harbouring around 580 species of birds, 271 species of fish, 174 mammals, 131 reptiles, 57 amphibians, and over 2000 species of plants (Tomas et al. 2019) and a variety of natural landscapes. The presence of these species confirms the importance of these areas in safeguarding essential environments for the conservation of endangered species populations (Smaniotto et al. 2024). Also provides ecosystem services (e.g., food, freshwater, and pastureland), regulating (e.g., climate stability and flood control) and cultural (e.g., scenic beauty, recreation, spiritual, and cultural diversity) (Moraes & Seidl 2000, Tomas et al. 2019).

*Mapping SNS*

Wantzen et al. (2023) documented 35 points from Sacred Natural Sites in the UPRB. Building on this dataset, we applied the snowball sampling method (Naderifar et al. 2017) to expand the map by incorporating the knowledge of local communities about additional sacred sites. We established a route through communication with researchers and professionals who work with the local communities and gave us references of key local people in the community. We engage with this people aiming to explore into their beliefs and pinpoint the specific places they hold as sacred. This snowball sampling technique enabled us to reach a broader comprehension of sacred places as perceived by various communities and was able to be done with the authorization number 46870121.9.0000.0021 granted by the ethics committee.

The engagement with these communities highlighted the rich cultural and social diversity of traditional communities in Brazil. “Traditional communities” in Brazil encompass a diverse set of social groups of multiple origins, with ways of life adapted to specific environments. In addition to Indigenous peoples and Quilombolas, they include groups such as riverine communities, rubber tappers, caiçaras, and babassu coconut breakers, among others. These communities share cultural, social, and economic practices passed down through generations, occupying approximately 25% of the national territory and representing around 25 million people (Fernandes-Pinto 2017).

Quilombos are formed by African descendants who, in the process of resistance to slavery, established groups that share cultural characteristics and occupy territories of common use. These groups, along with other traditional communities, represent diverse social origins and ways of life adapted to specific environments (Fernandes-Pinto 2022). For this study, we have chosen to use the term 'traditional communities' to encompass both Indigenous and Quilombo communities.

As diverse as these communities may be, Khan et al. (2008) emphasize that each Sacred Natural Site is imbued with its own unique myths, lore, and legends, making it distinctly significant to each group. For that reason, we define 4-points as criterion to be considered new areas of SNS: (i) active site with people visiting or/and performing ceremonies; (ii) site still maintained, but not necessarily in use (but the community didn't tear it down); (iii) a historically relevant site, with an intergenerational value; (iv) site legally delimited by historical-cultural value.

*Priority conservation and climate resilience areas datasets*

We used 2 recent studies as references, The Nature Conservancy research (2024) and Mapping the Ecological Corridos for UPRB (da Rosa Olivera 2024). The following criteria guided the choice of these datasets: (i) priority resilient climate change areas; (ii) ecological corridors for fauna connectivity. The selection of these parameters is justified because the identification of priority resilient areas relies on environmental conditions that indirectly ensure the presence and conservation of biodiversity. At the same time, the existence of

Ecological Corridors serves as a metric to assess biodiversity, as connected areas typically sustain higher levels of biological diversity (Mikusiński et al. 2014).

For (i) The Nature Conservancy's (2024) study identified Priority Resilient Climate Change areas in the Upper Paraguay River Basin (UPRB), including the Pantanal lowland and plateau. The term "resilient areas" in the study refers to locations characterized by high microclimatic diversity and connectivity, which are essential for the persistence of species and ecological processes in the context of regional climate change. This was achieved by combining two key metrics: landscape heterogeneity and local connectivity.

Landscape heterogeneity was assessed using four factors: topographic features, altitude variation, water availability, and soil diversity, which together capture microclimatic variability. Local connectivity was calculated based on resistance values assigned to land cover types, where natural areas had low resistance and urban zones high resistance. Connectivity was determined using a weighted average of resistance values within a defined spatial context.

The resilience of the landscape was calculated by combining the landscape heterogeneity and local connectivity layers. The resulting map divided areas into categories, highlighting regions where both metrics align to improve resilience. This approach pinpointed locations with high microclimatic diversity and permeable landscapes, providing essential conditions for species adaptation and persistence in the face of regional climate change. The methodology is detailed and available at the TNC study (2024): https://projeto-resiliencia-tnc.hub.arcgis.com/.

For (ii) da Rosa Oliveira et al. (2024) identified Ecological Corridors connecting priority forest and savanna areas (nodes) using the Least Cost Path (LCP) methodology. Nodes, defined as connection points ensuring corridor functionality, were selected based on patch size and core area size. In the Pantanal plain, only continuous areas larger than 10,000 hectares were considered, while in the highlands, remnants with core areas over 10 $km^2$ were included. Protected areas and Indigenous lands larger than 500 hectares were also incorporated as nodes. Focal species were selected to guide the construction of resistance matrices, following the umbrella species concept. Species were grouped based on their permeability patterns, and the group with the highest environmental requirements was chosen to represent the model. This ensured that the corridors were designed to support connectivity for a wide range of species.

Resistance matrices were constructed by assigning resistance values inversely proportional to the permeability of different land cover types. Least-resistance paths were modeled using the LCP method, and circuit theory was applied to analyze resistance variations along the corridors. Corridors were prioritized based on connectivity density, intersection with infrastructure, and areas of low permeability. Additionally, corridors affected by extensive vegetation loss after 2018 were excluded from the final map. The methodology is detailed in the research of da Rosa Olivera et al. (2024).

*Analysis*

For overlap analysis, we measured the percentage of the two different variables inside the SNS: (i) priority resilient climate change areas and (ii) ecological corridors for fauna connectivity. As there is a limitation for an exact definition of the boundaries of the sacred areas, we adopted the geographic coordinates collected from each SNS as a central spatial reference point, considering the ‘use for people’ of the area. This approach aligns with the methodology described by Lievano-Latorre et al. (2021), as their use of buffer zones demonstrates a practical solution to address spatial uncertainties. By referencing their methodology, we justify the adoption of buffer zones in our study to standardize the analysis and account for the lack of precise boundary definitions.

From this central point, a 5-radius buffer was generated using the Pairwise Buffer tool through ArcGIS Pro version 3.3.0 (Esri. 2024. ArcGIS Pro (Version 3.3.0) [Software]. Available at https://www.esri.com). We created 2, 5, 10, 15, and 20km buffers. For each variable (i and ii), we analyzed the percentage within each buffer and correlated it to evaluate at which buffer scale this correlation has the greatest value.

For (i) resilience areas: based on the results of the project developed by The Nature Conservancy (2024) (Figure 2), we used the maps with the results available on the project's website (Available at https://projeto-resiliencia-tnc.hub.arcgis.com/. Buffers were generated for each point, and the resilience raster was classified using an unsupervised method via the Train ISO Cluster tool, resulting in seven classes. Subsequently, the Tabulate Area tool was employed to calculate the area of each class within each buffer (zone data). Since our focus was on identifying priority areas for climate resilience, characterized by high local connectivity and landscape heterogeneity, we selected only the green color gradient, following the methodology of the reference study (TNC 2024, Rosenfield et al. submitted). Hence, we used the higher landscape resilience (Q4-green).

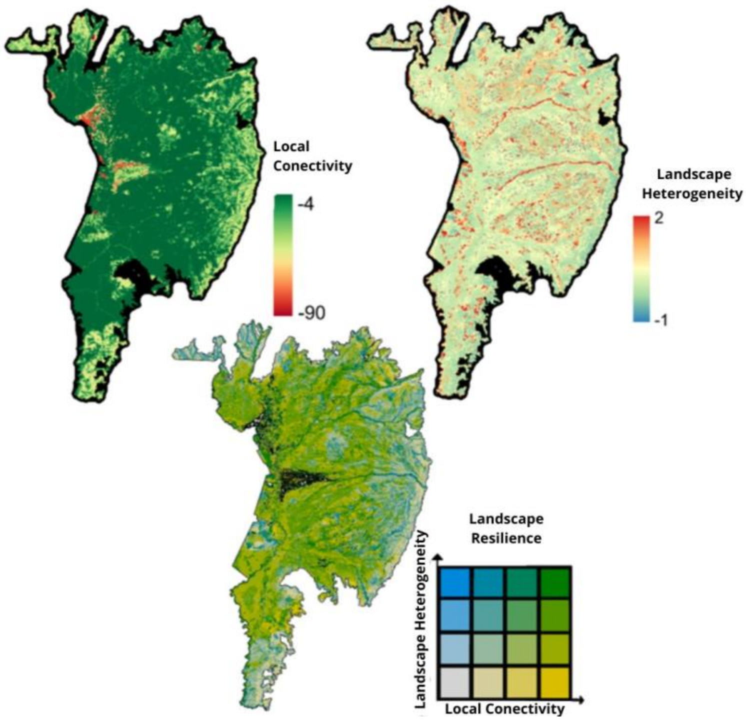


**Figure 2:** Priority Resilience Climate Change areas in Pantanal represented by colour gradient. Where dark green represents the priority resilience climate change area, combining higher landscape heterogeneity and higher local connectivity (Source: TNC 2024).

For (ii) ecological corridors: based on the findings of da Rosa Olivera et al. (2024) (Figure 3), buffers were generated for each point, and the ecological corridors within each buffer were extracted using the Pairwise Clip tool (Figure 4). The total area of each buffer was calculated using the Calculate Geometry tool, while the area of the corridors within the buffers was determined using the Summarize Within tool (ArcGIS Pro version 3.3.0 (Esri. 2024. ArcGIS Pro (Versão 3.3.0) [Software]. Available in https://www.esri.com). The percentage of corridor area relative to the total buffer area was then calculated. A table was created with these values (Table 1).

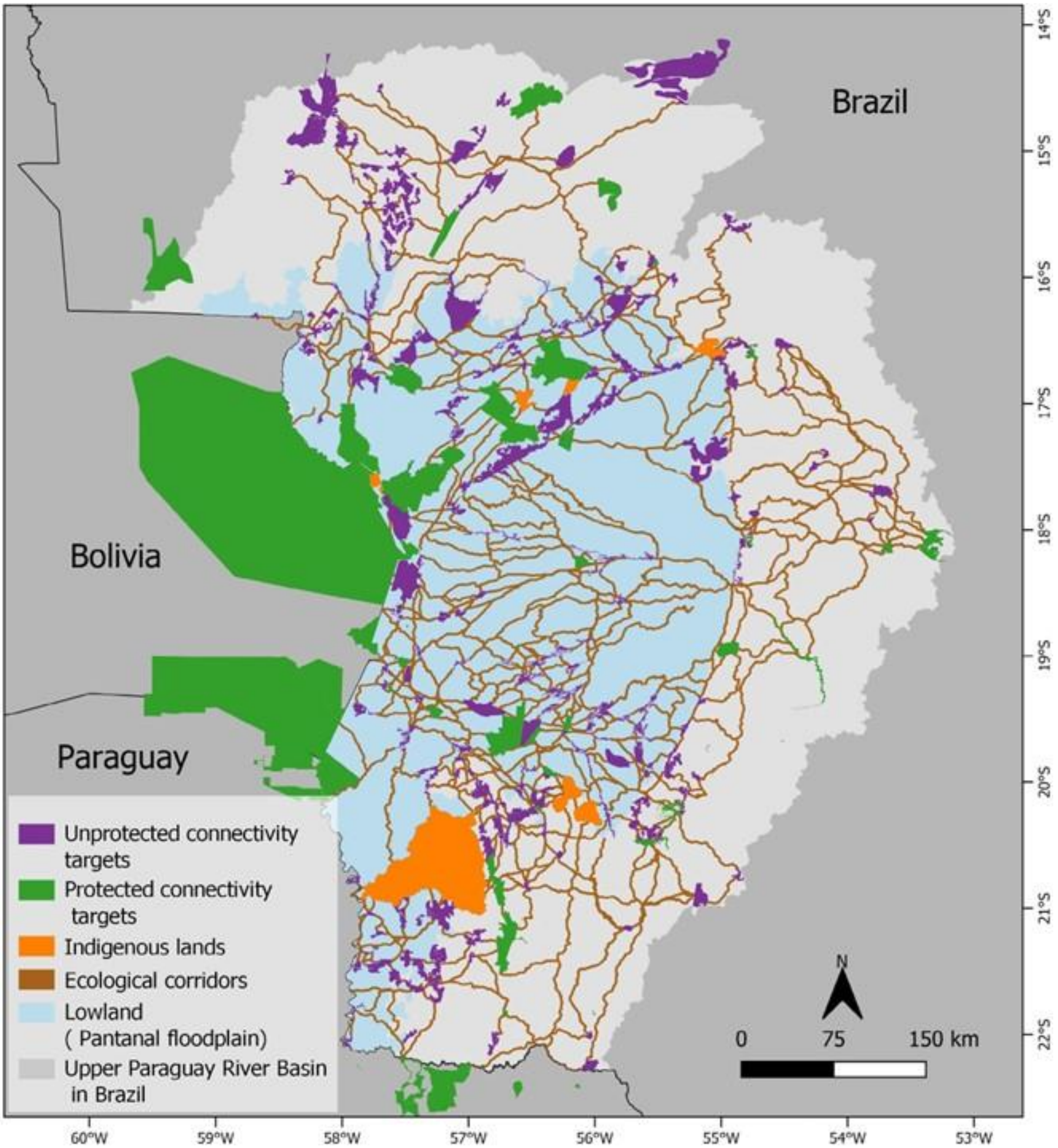


**Figure 3:** Least Cost Model, results showing the Ecological Corridors (brown) in the Upper Paraguay River Basin, Pantanal - lowland e Cerrado – plateau (Source: da Rosa Olivera et al. 2024).

We generated 500 random points, ensuring a minimum distance of 10 km between them, and applied the same procedures to calculate the percentage of Priority Resilience Climate Change areas and Ecological Corridors within the buffers of these random points (Figure 4).

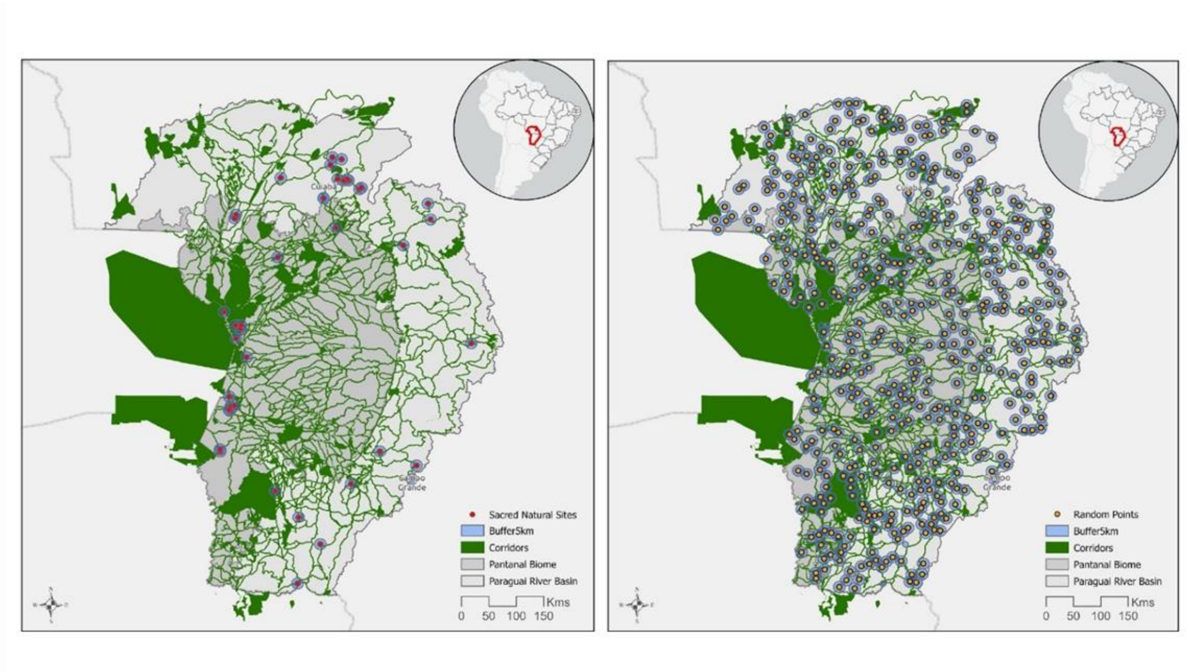


**Figure 4**: 5 km buffers in Sacred Natural Sites Points and Random Points inside the Upper Paraguay River Basin, Pantanal - lowland e Cerrado – plateau.

The random points were used as control areas, representing locations outside the perimeter of SNS sites. For the correlation analysis, we calculated the mean values within each kilometre of the buffers for both the SNS sites and the random points across the parameters (Table 1).

**Table 1:** Mean and Standard Deviation from Ecological Corridors e Priority Resilience Climate Change Areas inside Sacred Natural Sites and Random Points buffers.

| Ecological Corridors | | | Priority Resilience Climate Change Areas | |
|---|---|---|---|---|
| **Buffers** | **Mean** | **Stand. Deviation** | **Mean** | **Stand. Deviation** |
| SNS 2KM | 0,4636 | 0,3495 | 5,5942 | 24,7139 |
| Random 2KM | 0,2528 | 0,3276 | 0,1102 | 0,2065 |
| SNS 5KM | 0,415 | 0,2502 | 30,1561 | 158,1068 |
| Random 5KM | 0,2539 | 0,2595 | 47,5294 | 373,9846 |
| SNS 10KM | 0,382 | 0,2422 | 412,269 | 1611,4417 |
| Random 10KM | 0,2574 | 0,2183 | 89,1864 | 953,5497 |
| SNS15KM | 0,3683 | 0,2522 | 18,2671 | 61,734 |
| Random 15KM | 0,2573 | 0,1962 | 25,6655 | 239,6123 |
| SNS 20KM | 0,3597 | 0,2451 | 12,4529 | 29,2225 |
| Random20KM | 0,2594 | 0,1816 | 90,1573 | 1538,1186 |

To compare the percentage of the two parameters (Ecological Corridors and Priority Resilient Climate Change Areas) across the different areas (SNS and Random Points), we conducted a Monte Carlo t-test. The Monte Carlo t-test (Fisher-Pitman Permutation Test) is well-suited for our data because it is a robust and reliable method for comparing two groups (in this case, SNS and Random Points) when the traditional assumptions of parametric tests, such as normality, may not be satisfied. This non-parametric test is based on permutations, allowing it to calculate p-values without relying on normal distribution assumptions, making it highly effective for handling non-normal data (Zeghzeghi et al. 2010).

## Results

*Sacred Natural Sites – Reported areas*

For this study, we contacted and interviewed 11 researchers. Some of them are professors and researchers from the ecological and social areas and work directly with traditional and indigenous communities, which allowed us to gather valuable insights based on their knowledge. Additionally, 8 key individuals were identified as having significant expertise regarding Sacred Natural Sites (SNS) (Figure 5). These individuals were engaged through online meetings and three field visits, during which we interacted with members of two different communities. During these interactions, we explored their beliefs to understand whether they still regard certain places as sacred. This approach aligns with methodologies that emphasize the importance of participatory approaches and open-ended interviews to document community knowledge about sacred sites (Verschuuren et al. 2010).

We believe that open and fluid conversations, rather than structured interviews, are less likely to inhibit participants when discussing sensitive topics such as their beliefs. This approach is supported by studies that highlight the importance of creating a comfortable and respectful environment for participants, particularly when addressing cultural and spiritual values (Fernandes-Pintos et al 2015, Zannini et al 2021).

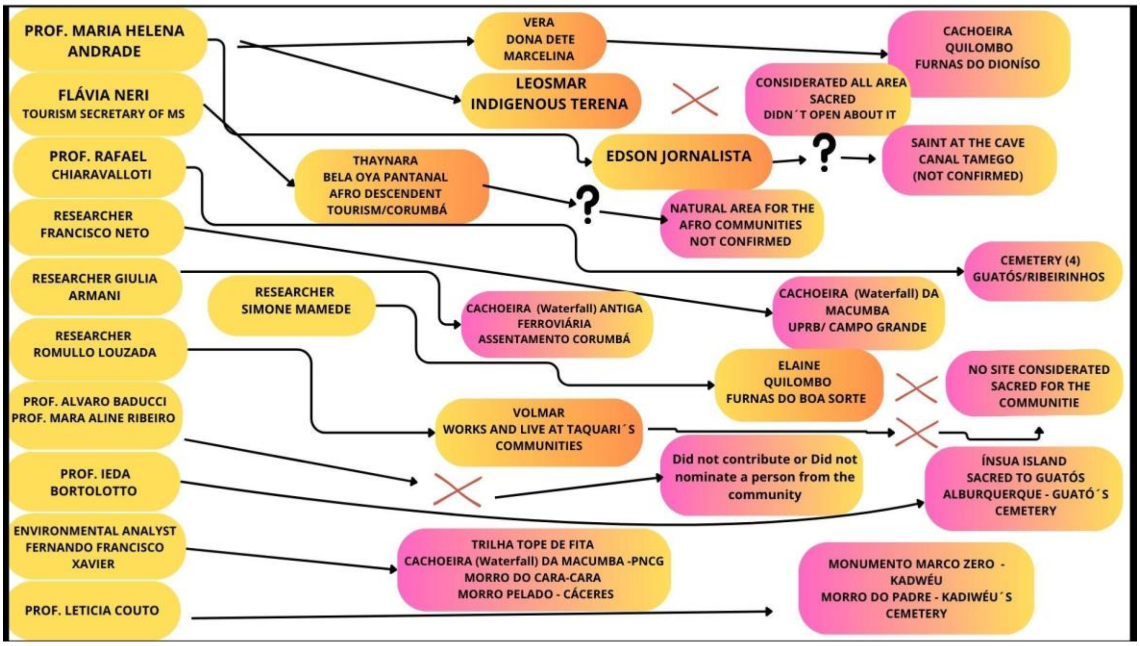


**Figure 5:** Histogram of contact network using the snowball methodology.

The yellow colours represent the professors and researchers, and the key people that we contact. And the yellow/pink colors represent the results of the interviews, the new Sacred Natural Sites or not.

We have in total 50 Sacred Natural Sites at UPRB (Figure 6). 33 reported by Wantzen et al. (2023), and 17 new sites (Supplementary material 4). The new sites are: “Trilha Tope de Fita” e “Cachoeira da Macumba” at “Parque Nacional Chapada dos Guimarães”, Mato Grosso (MT), “Cachoeira da Macumba” at Campo Grande, Mato Grosso do Sul (MS), “Quilombo Furnas do Dionísio” at Jaraguari/MS, 5 new points for “Cemitério Guató” all close to “Amolar Region” MS, “Cachoeira Antiga Ferroviária” at Corumbá/MS, “Morro Pelado” at Cáceres/MS, “Morro do Padre” at Rio Verde/MS, “Mirante Morraria do Sul – Kadiwéu” e “Monumento Marco Zero – Kadiwéu” at Kadiwéu land/MS, “Ilha Ínsua” by Paraguay river/MS, “Comunidade Albuquerque - Cemitério Guató” at Albuquerque/MS and “Baía Gaíva” in Paraguay river/MS (Figure 6).

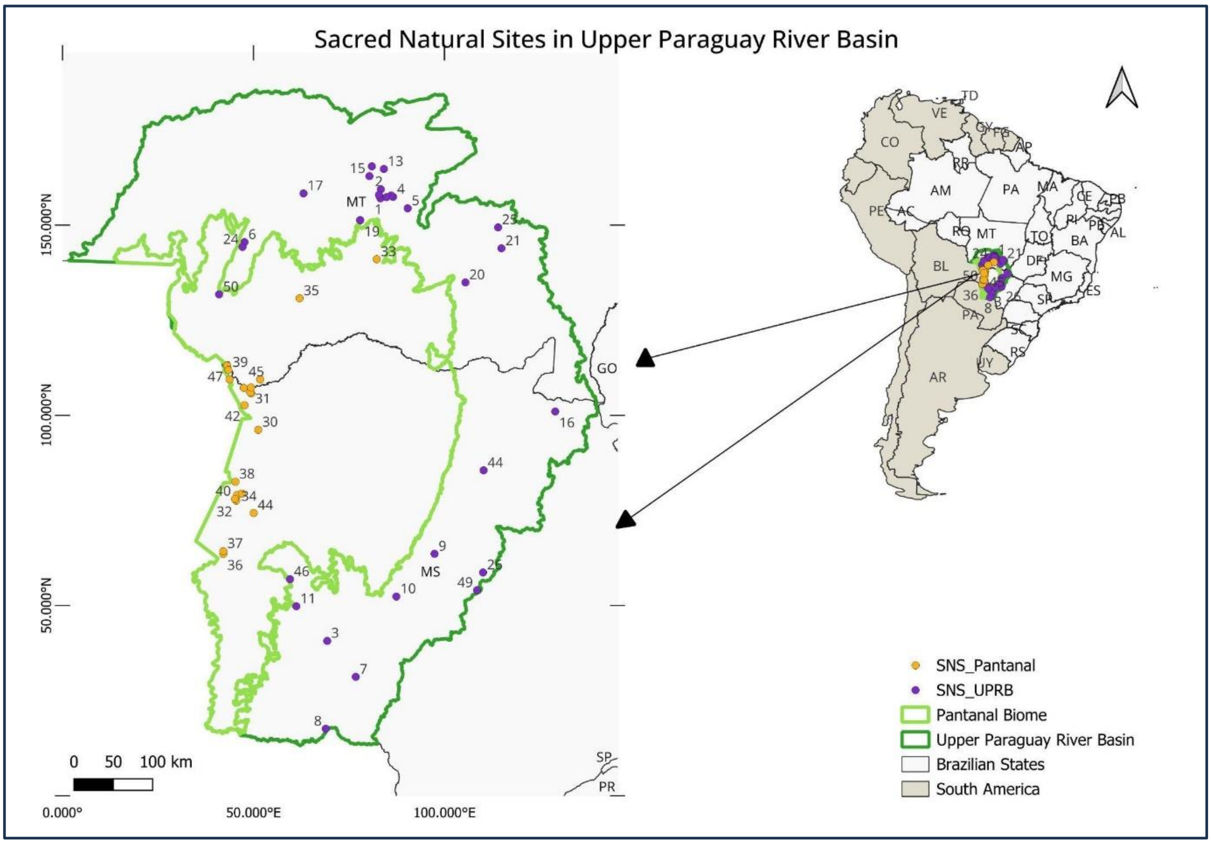


**Figure 6: Sacred Natural Sites in Upper Paraguay River Basin. 1:** Trilha Tope de Fita. **2**:Cachoeira da Macumba. **3**:Cachoeira Sinhorinho-Curandeiro. **4**:Centro Geodésico da América do Sul. **5**:Complexo de Caverna Aroe Jare. **6:**Dolina Água Milagrosa. **7**:Cemitério dos Herois. **8:** Nhandipa. **9:**Projeto Portal. **10:** Morro Paxixi. **11**: Mirante Morraria do Sul - Kadiwéu. **12**:Morrinho ou Toroari. **13**:Morro do Cambambe. **14**: Morro do Japão.**15**: Morro Só.**16:** Templo dos Pliares. **17:**Santa Elina. **18:**Morro de Santo Antônio. **19:**Morro de São Jerônimo. **20:** Cidade de Pedra.**21**: Jarudoré. **22:**Refúgio de Vida Silvestre Jamacá das Araras.**23**: Lapa do Frei Canuto. **24**:Serra Ponta do Morro.**25:** Morro da Mesa. Morro do Cambambe. **26:** Quilombo Furnas do Dionísio. **27-31**:Cemitério Guató. **32:**Cachoeira Antiga Ferroviária/Corumbá. **33**:Baía Chacororé. **34:**Morro Santa Cruz.**35**: Pixaim - Culto Água.**36**: Forte de Coimbra - Nossa Senhora do Carmo. **37**: Gruta Ricardo Franco - Águas Milagrosas. **38:**Morro do Cruzeiro - Cristo Rei do Pantanal/ via sacra. **39**: Cemitério Guató.**40**: Crosta laterítica - inscrições rupestres. **41:** Crosta laterítica - inscrições rupestres. **42**:Pedra Baía Mandioré. **43**:Morro Pelado/Cáceres. **44**:Morro do Padre. **45**:Morro do Cara-Cara. **46**: Monumento Marco Zero - Kadiwéu. **47**: Ilha Ínsua.**48**: Comunidade Albuquerque - Cemitério Guató. **49**: Cachoeira da Macumba - PNCG. **50**: Baía Gaíva.

The Monte Carlo t-test results demonstrated statistical significance (p-values < 0.05) for Ecological Corridors, indicating a higher overlap of Ecological Corridors between the Sacred Natural Sites (SNS). The analysis revealed that smaller buffer sizes showed a slight positive difference in the percentage of Ecological Corridors compared to larger buffers, suggesting that the scale of analysis influences the observed patterns (*Supplementary material 2*).

For Priority Resilience Climate Change areas, we also conducted the Monte Carlo t-test to assess if the results were significant. In all buffers, the differences between the means of SNS and Random Points are small (ranging from 0.001 to 0.026) indicating similarity between the analyzed groups (*Supplementary material 2*). The p-value for all comparisons is greater than $p<0.05$, indicating no statistical significance between the percentage of Priority Resilience Climate Change areas for SNS and Random Points in any of the buffers.

*Traditional Communities and their connection to Sacred Natural Sites*

From 50 Sacred Natural Sites, 16 are located in Conservation Units neighboring Indigenous areas. We have 1 point that is exactly in a Conservation Unit, “Parque Nacional do Pantanal Mato Grossense” which is also an Indigenous land. Other locations that are nearby Indigenous lands (like Parque Nacional da Chapada dos Guimarães). For Indigenous areas, we have 5 SNS points and 1 SNS in the Quilombo land. All the others Sacred Natural Site are on private land.

**Table 2**: Overlap between Sacred Natural Sites inside Conservation Units, Indigenous or Quilombo land.

| **Sacred Natural Sites** | **Id Map** | **Pantanal/ UPRB** | **Conservation Unit Name** | **Category e Use** | **Indigenous Land** | **Quilombo Land** |
|---|---|---|---|---|---|---|
| Cachoeira da Macumba | 2 | UPRB | Parque Nacional da Chapada dos Guimarães | Federal_protected_area_ integral_protection | | |
| Trilha Tope de Fita | 1 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Centro Geodésico da América do Sul | 4 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Complexo de Caverna Aroe Jare | 5 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Morrinho ou Toroari | 12 | UPRB | Monumento Natural Morro de Santo Antônio | State_protected_area_ integral_protection | | |
| Morro do Cambambe | 13 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Morro do Japão | 14 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Morro Só | 15 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_ sustainable_use | | |
| Templo dos Pliares | 16 | UPRB | Parque Natural Municipal Templo dos Pilares | Municipality_protected_area_ integral_protection | | |
| Morro de Santo Antônio | 18 | UPRB | Monumento Natural Morro de Santo Antônio | State_protected_area_ integral_protection | | |
| Morro de São Jerônimo | 19 | UPRB | Parque Nacional da Chapada dos Guimarães | Federal_protected_area_ integral_protection | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cidade de Pedra | 20 | UPRB | Reserva Particular do Patrimônio Natural Parque Ecológico João Basso | Federal_protected_area_sustainable_use | | |
| Refúgio de Vida Silvestre Jamacá das Araras | 22 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_sustainable_use | | |
| Lapa do Frei Canuto | 23 | UPRB | Área de Proteção Ambiental da Chapada dos Guimarães | State_protected_area_sustainable_use | | |
| Cemitério Guató | 29 | Pantanal | Reserva Particular do Patrimônio Natural Fazenda Acurizal e Fazenda Penha | Federal_protected_area_sustainable_use | | |
| Cemitério Guató | 31 | Pantanal | Parque Nacional do Pantanal Mato-grossense | Federal_protected_area_integral_protection | | |
| Mirante Morraria do Sul - Kadiwéu | 11 | UPRB | | | Kadiwéu | |
| Jarudoré | 21 | UPRB | | | Jarudoré | |
| Monumento Marco Zero - Kadiwéu | 46 | UPRB | | | Kadiwéu | |
| Ilha Ínsua | 47 | Pantanal | | | Guató | |
| Cemitério Guató | 39 | Pantanal | | | Guató | |
| Quilombo Furnas do Dionísio | 26 | UPRB | | | | Quilombo Furnas do Dionísio |

## Discussion

*Sacred Natural Sites, Ecological Corridors, and Resilience areas*

As highlighted in our results, the relationship between sacred areas and biodiversity—specifically Ecological Corridors—exhibits a consistent positive pattern across different scales. However, the association between Priority Resilience Climate Change areas and Sacred Natural Sites (SNS), while positive, lacks significance across scales. This indicates that in some instances, the agendas of conserving corridors and sacred areas work synergistically due to their spatial and functional overlap. In other cases, these conservation efforts may need to be pursued as complementary strategies to achieve broader ecological goals.

As outlined in our hypothesis, a significant correlation was observed across all scales in the context of Ecological Corridors, with a clear trend: smaller scales exhibited a higher percentage of ecological corridors, which progressively declined as the scale increased. Regarding Priority Resilience Climate Change areas, no significant difference was observed between SNS and other areas. This lack of a clear relationship can be attributed to the criteria used to define Priority Resilience Climate Change areas and the unique characteristics of the wetland ecosystem. The methodology employed by The Nature Conservancy (TNC 2024) to identify these areas assigns relatively high scores of heterogeneity to regions exhibiting diverse microhabitats and dynamic ecological processes, particularly in wetlands, where the wetland area index plays a significant role. However, in regions like the Pantanal, overall landscape heterogeneity is low (7.4%), as the dominance of flat relief reduces the influence of variables such as relief diversity and altitude variation. This highlights the unique characteristics of the Pantanal, where small variations in relief and the presence of wetlands create localized heterogeneity and could also influence the result.

These areas, while ecologically valuable, may have historically been unstable or less suitable for human use, resulting in their omission as sites for cultural or ceremonial activities, unlike the more stable regions that are often chosen for SNS (Sullivan et al. 2024). The selection of random points in areas distant from SNS posed limitations, particularly in regions with low human impact. Including non-sacred areas with higher anthropogenic pressures could alter the outcomes (Sullivan et al. 2024).

Moreover, the natural flood-and-drought regime of the Pantanal creates a dynamic ecological mosaic (Wantzen et al. 2023), which makes it challenging to identify clear differences between Sacred Natural Sites (SNS) and other regions. The prevalence of sampling points within flooded areas likely influenced the study results. These dynamic water cycles also discourage permanent settlement in the floodplain, as local livelihoods are directly or indirectly affected by seasonal flooding (Chiaravalloti 2019). Additionally, results might differ in contexts with varying levels of human activity pressure or different land-use types across protected versus unprotected areas (Sullivan et al. 2024).

The Pantanal encompasses 38.1% of the Priority Climate Change Resilience Areas, with most of these areas concentrated in the lowland (flooded regions), compared to 16.6% in the plateau region of the UPRB (TNC 2024). Connectivity decreases significantly near the biome’s borders with the Cerrado and Amazon, where the transition to more fragmented and anthropized landscapes may have influenced the results. Although rivers, lakes, and wetlands were considered during the construction of the heterogeneity and connectivity layers, these ecosystems were ultimately masked in the final resilience map and not classified into any resilience category (TNC 2024). This may also have influenced the representation of resilience areas concerning SNS, as aquatic ecosystems are crucial for maintaining connectivity and supporting ecological processes in the Pantanal. In summary, these findings suggest that while Priority Resilience Climate Change areas prioritize ecological resilience under climate change, their overlap with SNS may be limited due to differing selection criteria. This highlights the importance of complementary approaches that integrate cultural heritage and climate resilience into conservation planning.

*Study Limitations*

Although our study demonstrated relationship specially between Ecological Corridos it is important to highlight some methodological challenges that could be addressed in future research.

First, the snowball methodology proved effective in identifying additional SNS; however, broader coverage could be achieved through enhanced engagement with local communities, ensuring the inclusion of diverse perspectives and knowledge systems.

Second, the variability in the scale of Sacred Natural Sites (SNS) posed significant challenges for spatial analyses. As highlighted by Wild & McLeod (2008), SNS can range from small, localized features, such as a single tree or rock formation, to vast landscapes, such as entire mountain ranges or river systems. This variability of size and buffer sizes complicates the precise definition of boundaries, as some SNS encompass entire landscapes that contain smaller, highly significant sacred sites within them and that may also have impacted the findings, as observed in studies on sacred forests (Sullivan et al. 2024), and this influence could be more pronounced in flooded areas.

Furthermore, the governance and recognition of SNS often operate at multiple scales—local, national, and international—requiring tailored approaches to conservation and spatial analysis (Verschuuren et al. 2010). Future studies could benefit from integrating more systematic methodologies to define and map SNS boundaries, while also engaging local communities to ensure the inclusion of diverse cultural and spiritual perspectives.

The underrepresentation of African-descendant communities, such as Quilombos, highlights gaps in SNS identification. This issue stems from historical processes of colonization and the ongoing marginalization of their cultural and territorial rights (Bispo 2015). This is particularly relevant as Afro-descendant religions that often use natural elements, such as waterfalls, to manifest their beliefs and connect with nature. This underrepresentation also reflects broader patterns of ecological racism, as highlighted by Fernandes-Pinto et al. (2022). These patterns marginalize traditional communities within conservation policies, limiting their ability to fully protect and manage their territories.

Promoting more inclusive frameworks that integrate their rights and knowledge systems is essential for equitable and effective conservation efforts.

## Conclusion

*Implications for Conservation and Territorial Planning*

Our study shows that Sacred Natural Sites (SNS) play a critical role in biodiversity conservation in the Upper Paraguay River Basin. These sites, located in both the Pantanal lowlands and Cerrado plateau, frequently overlap with Ecological Corridors and Protected areas.

Additionally, our findings address the scarcity of data from South America in global studies on the relationship between Sacred Natural Sites and biodiversity, as highlighted by Sullivan et al. (2024), who noted a significant regional bias in the literature, with the majority of studies focusing on Asia, Africa, and Europe, and only one study from the Americas included in their meta-analysis. Overall, our results align with previous research emphasizing the ecological importance of sacred forests, highlighting their contribution to biodiversity conservation and the maintenance of ecosystem services (Frascaroli et al. 2019, Dawson et al. 2021, Zannini et al. 2021, Sullivan et al. 2024).

Building on these findings, Sacred Natural Sites offer complementary means for conservation in the Upper Paraguay River Basin (UPRB), providing ecological and cultural benefits. These sites can be integrated into global conservation strategies, aligning with the CBD's Target 3 to conserve 30% of terrestrial and aquatic areas by 2030. They meet many criteria for designation as Other Effective Area-Based Conservation Measures (CBD/COP/DEC/15/4).

However, successful integration requires governance structures that respect and accommodate the cultural, ecological, and spiritual dimensions of these sites. Effective governance must address the involvement of multiple stakeholders, including Indigenous peoples, local communities, and governmental bodies, ensuring that decision-making processes are inclusive and equitable. This is particularly important in regions like the Pantanal, where the interplay between ecological resilience and cultural heritage requires specific approaches to management and conservation (Bolzan et al. 2022).

Our mapping reveals that some SNS were identified within Federal Conservation Units, as well as in state-regulated areas such as RPPNs (Private Reserves of Natural Heritage) and APAs (Environmental Protection Areas), including the APA Baía Negra and the RPPN Sesc Pantanal, which are key areas for biodiversity conservation and cultural heritage in the Pantanal. Additionally, SNS were also identified in areas with no formal protection, such as sacred sites located near traditional communities and Indigenous territories, emphasizing the need for inclusive conservation strategies.

At the policy level, these spatial relationships between SNS and other conservation areas could inform the development of public policies, especially at the state level, where implementation is more feasible. State-level policies offer greater flexibility to address the specific ecological and cultural dynamics of regions like the Pantanal. They also allow for closer collaboration with local stakeholders, such as landowners and community leaders, enabling the co-creation of initiatives that integrate conservation with sustainable development. For example, Guerra et al. (Unpublished) highlight the Payment for Ecosystem Services Law in Mato Grosso do Sul (Law #5235/2018), a successful regional model that has been instrumental in promoting sustainable practices and engaging stakeholders, demonstrating how state-level initiatives can align ecological conservation with socioeconomic development. Providing subsidies to landowners would further incentivize them to protect sacred sites, particularly in the Pantanal, where less than 6% of the area is formally protected (Tomas et al. 2019).

Addressing challenges such as low environmental awareness among decision-makers and socioeconomic inequalities through targeted public policies, restoration programs, and payments for ecosystem services could strengthen conservation efforts and promote sustainable development in the region (Bolzan et al. 2022).

Furthermore, integrating ecosystem services with human well-being is essential. Bolzan et al. (2022) highlight that the Pantanal's ecosystem services—including climate regulation, flood control, and cultural values—directly contribute to human well-being. Sacred Natural Sites (SNS) particularly enhance spiritual well-being through people's connection with nature, emphasizing the need to incorporate cultural and spiritual dimensions into conservation strategies (Marselle et al. 2019). These dimensions should be recognized as cultural services within ecosystem frameworks and included in payment schemes like Payments for Ecosystem Services (PES). Such an approach not only promotes biodiversity conservation but also strengthens the connection between human well-being and cultural heritage preservation.

This study highlights the vital role of traditional communities, particularly Indigenous groups, in the conservation of protected areas, emphasizing the need for equity by recognizing their rights, knowledge, and practices (Gurney et al. 2023).

Among the 50 Sacred Natural Sites (SNS) identified, 16 are situated within or in close proximity to Indigenous lands. For example, the “Parque Nacional do Pantanal Matogrossense” overlaps with “Guató” Indigenous land, showcasing how Indigenous ecological knowledge contributes to the preservation of well-maintained ecosystems. Combining this traditional knowledge with scientific approaches could help develop strategies to combat challenges such as deforestation, agricultural expansion, and climate change.

The active participation of Indigenous and Quilombola communities in conservation planning is essential for building resilience and fostering sustainable, inclusive approaches to managing the Pantanal ecosystem. Research indicates that involving traditional communities in the governance of Protected Areas enhances their management effectiveness (Austin 2018).

As emphasized by Zank et al. (2025), conservation should not be about us, but about them—the true guardians of the land. Recognizing this is not only a matter of justice but also a crucial step toward achieving genuinely sustainable and inclusive conservation outcomes (Zank et al. 2025).

## General Conclusion

This research highlights the critical role of Sacred Natural Sites (SNS) as essential components of biodiversity conservation and climate resilience strategies. By bridging ecological, cultural, and spiritual dimensions, SNS offers a complementary approach to traditional conservation frameworks, aligning with global targets such as the Kunming-Montreal Global Biodiversity Framework. The findings emphasize the importance of recognizing the knowledge, practices, and rights of Indigenous and traditional communities, whose stewardship has been fundamental to the preservation of these landscapes.

The spatial analysis revealed that SNS often overlap with Ecological Corridors, underscoring their role in maintaining connectivity and supporting biodiversity. However, the limited overlap with Priority Resilience Climate Change areas highlights the need for more nuanced approaches that consider the unique characteristics of wetland ecosystems and the dynamic nature of landscapes like the Pantanal. These results reinforce the importance of integrating SNS into conservation planning, not only for their ecological value but also for their cultural and spiritual significance.

Governance remains a critical factor in ensuring the effective protection and management of SNS. Addressing challenges such as the underrepresentation of Quilombola communities and the fragile land rights framework in Brazil is essential to achieving equitable and inclusive conservation outcomes. By fostering collaboration between scientific and traditional knowledge systems, conservation strategies can become more inclusive, sustainable, and resilient.

In conclusion, conservation efforts should center on the communities that have long been the stewards of these lands. Their knowledge, practices, and rights are fundamental to any successful conservation strategy.

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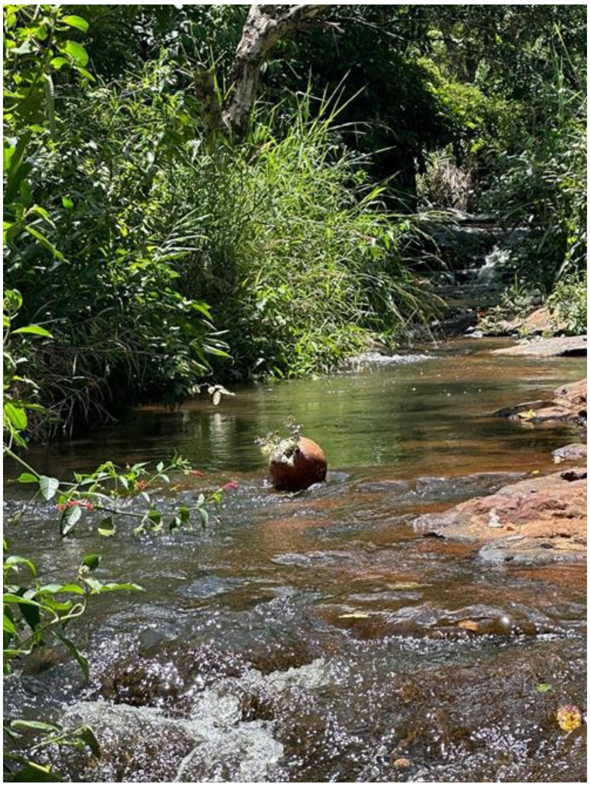
## Supplementary Material

*Supplementary material 1: Pictures from field trips to investigate some new areas of Sacred Natural Sites.*

Picture 1 e 2: Waterfall "Cachoeria da Macumba" in Campo Grande/MS.



Picture 3 e 4: Waterfall at "Quilombo Furnas do Dionísio" /MS.

Picture 5 e 6: Field trip to “Quilombo Furnas da Boa Sorte” /MS.

This Quilombo is not considered a Sacred Site, which may be related to the assimilation of cultures over time. All the Quilombos in this region originated from the same area, Minas Gerais, a state historically known for its Afro-descendant population who worked in the mines. It is likely that these communities were initially brought from Bahia, a region where ships carrying enslaved African people arrived. Although they have roots in Afro-descendant religions, today, most members of these communities identify as Christians.

*Supplementary material 2: Results of t-Test Monte Carlo permutation analyses for all different Buffer sizes for Ecological Corridors e Priority Resilience Climate Change Areas*

**Table 3**: T-test Monte Carlo permutation for Ecological Corridos e Priority Resilience Climate Change areas

| Ecological Corridors | SNS_2km | Random_2km | SNS_5km | Random_5km | SNS_10km | Random_10km |
|---|---|---|---|---|---|---|
| **N:** | 50 | 500 | 50 | 500 | 50 | 500 |
| **Mean:** | 0,4636 | 0,25276 | 0,41505 | 0,25391 | 0,38203 | 0,25744 |
| **95% conf.:** | (0,36427 0,56292) | (0,22397 0,28154) | (0,34395 0,48615) | (0,23111 0,27671) | (0,31321 0,45085) | (0,23826 0,27662) |
| **Variance:** | 0,12215 | 0,10734 | 0,062585 | 0,067344 | 0,058645 | 0,047651 |
| **Diff. between means** | 0,21084 | | 0,16114 | | 0,12459 | |
| **95% conf. interval (parametric):** | (0,1148 0,30688) | | (0,08577 0,23651) | | (0,060337 0,18884) | |
| **95% conf. interval (bootstrap):** | (0,11118 0,30915) | | (0,087952 0,23339) | | (0,053899 0,19244) | |
| **t :** | 4,3121 | | 4,1997 | | 3,8089 | |
| **p (same mean):** | 1,92E-05 | | 3,12E-05 | | 0,00015538 | |
| **Critical t value (p=0.05):** | 1,9643 | | 1,9643 | | 1,9643 | |
| **Uneq. var. t :** | 4,0898 | | 4,3277 | | 3,4985 | |
| **p (same mean):** | 0,00013494 | | 5,79E-05 | | 0,0009124 | |
| **Monte Carlo permutation:p (same mean):** | 0,0001 | | 0,0001 | | 0,0002 | |
| **Priority Resilience Climate Change areas** | | | | | | |
| **N:** | 50 | 500 | 50 | 500 | 50 | 500 |
| **Mean:** | 0,10886 | 0,11022 | 0,10619 | 0,11058 | 0,096995 | 0,10999 |
| **95% conf.:** | (0,049382 0,16834) | (0,092069 0,12837) | (0,059088 0,15329) | (0,093985 0,12718) | (0,061908 0,13208) | (0,094844 0,12514) |
| **Variance:** | 0,0438 | 0,042662 | 0,027469 | 0,035675 | 0,015243 | 0,029722 |
| **Diff. between means** | 0,001358 | | 0,0043907 | | 0,012997 | |
| **95% conf. interval (parametric):** | (-0,058892 0,061608) | | (-0,05007 0,058852) | | (-0,036127 0,06212) | |
| **95% conf. interval (bootstrap):** | (-0,05468 0,067207) | | (-0,041057 0,055636) | | (-0,022424 0,05137) | |
| **t :** | 0,044274 | | 0,1583 | | 0,5197 | |
| **p (same mean):** | 0,964 | | 0,87423 | | 0,60348 | |
| **Critical t value (p=0.05):** | 1,9643 | | 1,9643 | | 1,9643 | |
| **Uneq. var. t :** | 0,04379 | | 0,17623 | | 0,68093 | |
| **p (same mean):** | 0,96521 | | 0,86068 | | 0,49817 | |
| **Monte Carlo permutation:p (same mean):** | 0,9646 | | 0,8728 | | 0,605 | |

| Ecological Corridors | SNS_15km | Random_15km | SNS_20km | Random_20km |
|---|---|---|---|---|
| N: | 50 | 500 | 50 | 500 |
| Mean: | 0,3683 | 0,25732 | 0,35973 | 0,25938 |
| 95% conf.: | (0,29663 0,43998) | (0,24009 0,27456) | (0,29008 0,42938) | (0,24343 0,27534) |
| Variance: | 0,06361 | 0,038476 | 0,060069 | 0,032971 |
| Diff. between means | 0,038476 | | 0,10034 | |
| 95% conf. interval (parametric): | (0,052188 0,16978) | | (0,045531 0,15516) | |
| 95% conf. interval (bootstrap): | (0,038427 0,1791) | | (0,029657 0,16778) | |
| t : | 3,7079 | | 3,596 | |
| p (same mean): | 0,00023028 | | 0,00035238 | |
| Critical t value (p=0.05): | 1,9643 | | 1,9643 | |
| Uneq. var. t : | 3,0215 | | 2,8187 | |
| p (same mean): | 0,0038101 | | 0,0067066 | |
| Monte Carlo permutation:p (same mean): | 0,0002 | | 0,0002 | |
| Priority Resilience Climate Change areas | | | | |
| N: | 50 | 500 | 50 | 500 |
| Mean: | 0,093293 | 0,1086 | 0,09416 | 0,12069 |
| 95% conf.: | (0,059536 0,12705) | (0,094346 0,12286) | (0,060558 0,12776) | (0,10673 0,13466) |
| Variance: | 0,014108 | 0,02632 | 0,013979 | 0,025256 |
| Diff. between means | 0,015308 | | 0,026535 | |
| 95% conf. interval (parametric): | (-0,030968 0,061585) | | (-0,018834 0,071903) | |
| 95% conf. interval (bootstrap): | (-0,018647 0,052043) | | (-0,0073373 0,063252) | |
| t : | 0,64979 | | 1,1489 | |
| p (same mean): | 0,5161 | | 0,25111 | |
| Critical t value (p=0.05): | 1,9643 | | 1,9643 | |
| Uneq. var. t : | 0,83662 | | 0,14876 | |
| p (same mean): | 0,4057 | | 0,2459 | |
| Monte Carlo permutation:p (same mean): | 0,5231 | | | |

*Supplementary material 3: Maps with Sacred Natural Sites in Conservation Unit, Quilombo Land and Indigenous Land.*

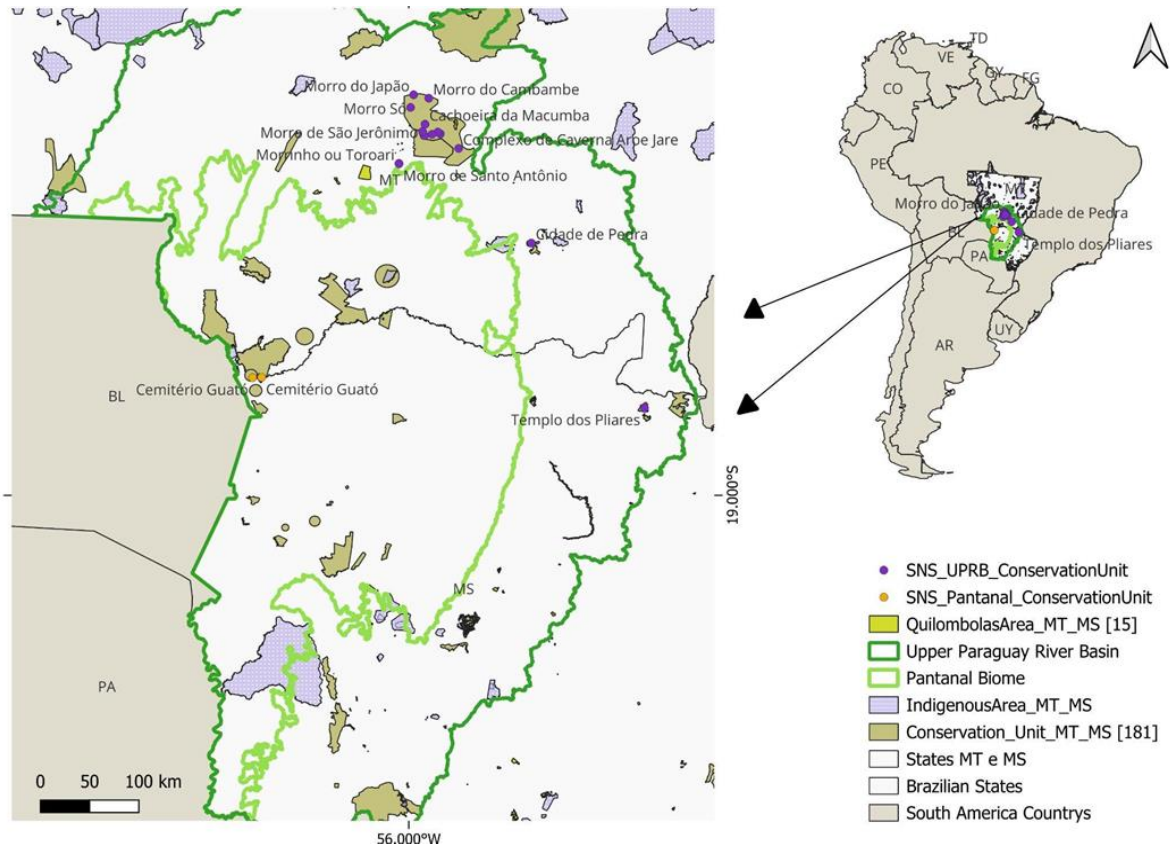



**Figure 7**: Sacred Natural Sites in Conservation Units.

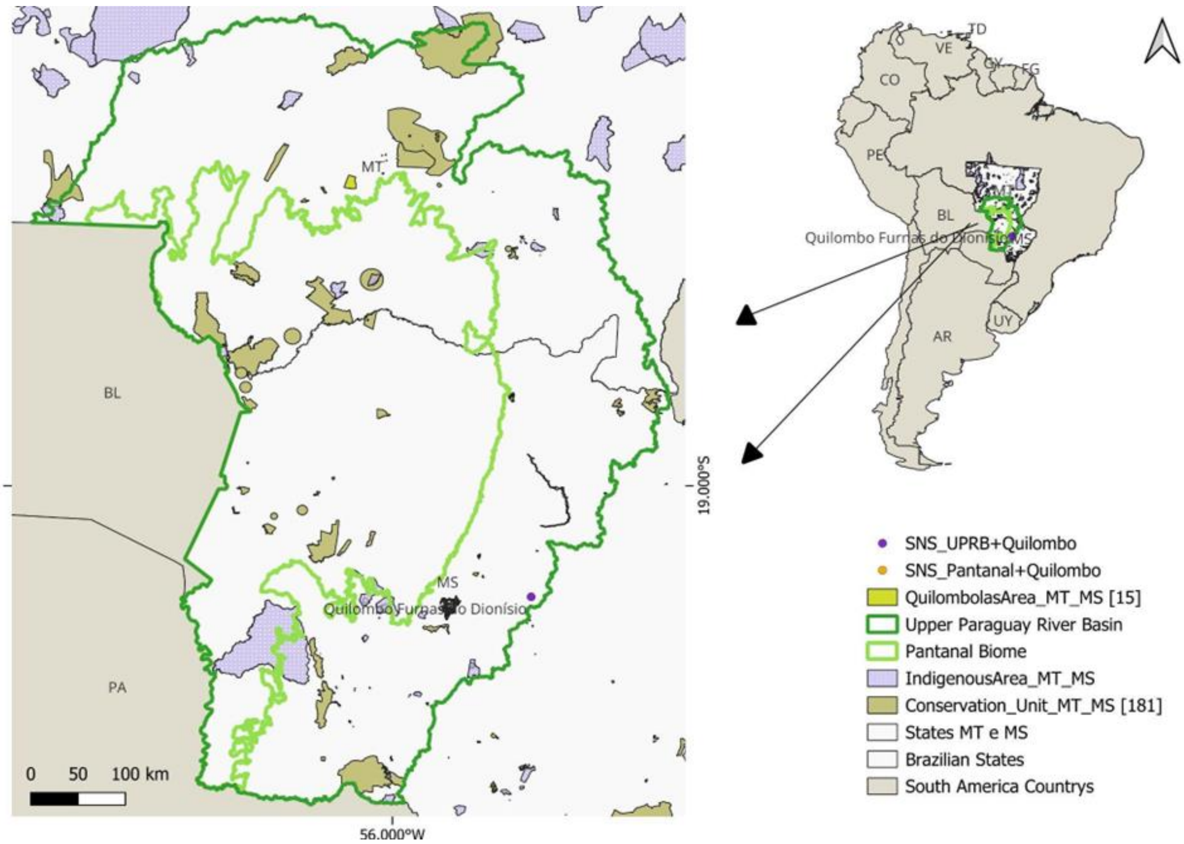



**Figure 8**: Sacred Natural Sites in Quilombo land "Furnas do Dionísio".

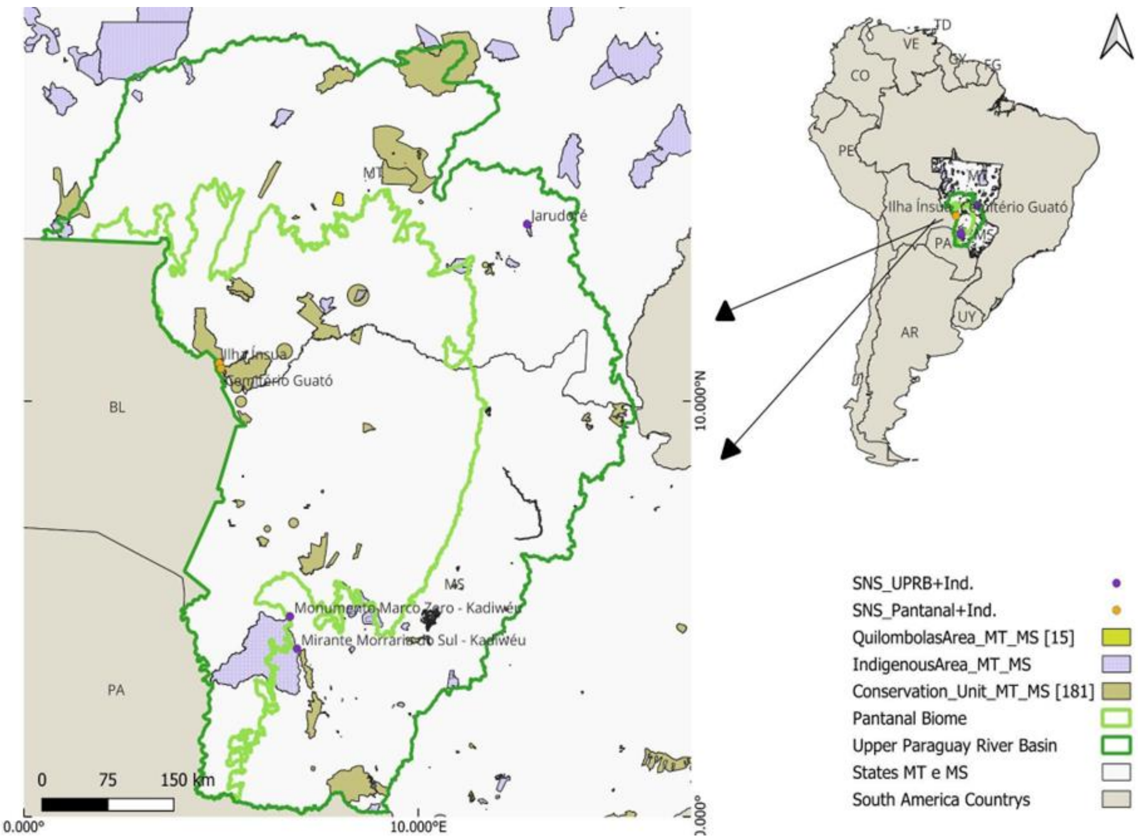



**Figure 9**: Sacred Natural Sites in Indigenous Land.

*Supplementary material 4: Stories about Sacred Natural Sites*

1.Trilha Tope de Fita (“Tope de Fita Trail) – Chapada dos Guimarães/MT: This was one of many routes used to connect Cuiabá to Chapada dos Guimarães. Historically significant, this path was likely established after the ascent of white settlers to the highlands, first recorded in 1727. However, some authors suggest that the Tope de Fita Trail may have been part of an Inca route. It was also an ancient pilgrimage path, associated with the patron saint of the city of Chapada dos Guimarães, Saint Anne (Sant’Anna).

2. Cachoeira da Macumba (Waterfall)- Parque Nacional da Chapada dos Guimarães/MT: A site where African-based religions practice their faith.

3. Cachoeira do Sinhozinho Curandeiro (Sinhozinho´s Waterfall  Healer) - Bonito/MS: Estância Mimosa - Sinhozinho, a healer who is part of Bonito's history, trapped a giant snake in one of the region's caves. At the place where the serpent was imprisoned, Sinhozinho placed a holy cross, which should not be removed, or else the serpent will be released and terrorize the city. Sinhozinho appeared in Bonito and began healing the sick in the 1940s. Compared to the biblical figure John the Baptist, Sinhozinho visited the people of Bonito and used natural elements (herbs, ashes, water) to heal the sick. Some say that Sinhozinho was killed by those who felt "threatened" by his notoriety, and here another part of the legend arises. Some say his body was cut up and each part thrown into the rivers, which would explain the crystalline nature of the waters in this region of the Serra da Bodoquena.

4. Centro Geodésico da América do Sul (Geodesic Center of South America) – Cuiabá/MT: The city of Cuiabá is located in the most central part of South America, exactly at its geodesic center.

5. Complexo de Caverna Aroe Jare (Aroe Jare Cave Complex) - Fazenda Água Fria/Chapada dos Guimarães/MT: Includes the Aroe Jari Caves, Gruta Azul, Kiogo Brado Caves, and Pobe Jari. "It is known from the various signs left behind that prehistoric man already walked

through the cave region, leaving signs in sheltered places not susceptible to intense erosion. The Indigenous from Bororo ethnicity, who inhabited the Chapada, and even the Caiapós more recently, may have used it as an overnight stay during a hunting trip or in search of medicinal herbs, and there is a mention that the Tropeiros, already in the Portuguese colonial production mode, would have stayed overnight in 1870 when they were on their way to Cuiabá. Aroe Jari Cave - Aroe Jari is a name of indigenous origin that means "dwelling of souls." Cataloged as the largest sandstone cave in Brazil, Aroe Jari impresses with its size and grandeur, as it has 1550 meters of extension, several forks, and rooms.

6. Dolina Água Milagrosa (Miraculous Water Sinkhole) – Cáceres/MT: The lagoon is about 25 km from the center of Cáceres, in the Piraputanga region. The rumors about the Dolina da Água Milagrosa don't stop there. It receives this name because, for the residents of the region, the water has incredible medicinal properties, being able to cure skin, kidney, and liver diseases, even cancer.

7. Cemitério dos Heróis (Heroes' Cemetery) – Jardim/MS - A historical heritage site in the city of Jardim, Mato Grosso do Sul. It is located on the left bank of the Miranda River. A site of historical interest related to the Retreat from Laguna, Paraguayan War (1864-1870). During the Retreat (January to May 1867), three of its leaders died of cholera; during the work of the Brazilian border demarcation commission in 1872, the site was marked by a plaque that still exists on one of the tombs.

8. Nhandipa – Bela Vista/MS: place where the first land battle of the Laguna Retreat took place on May 11/1867, on the banks of the Apa River between Brazilians and Paraguayans. A cultural richness that recalls the biggest war Brazil has ever faced, the war between Brazil and Paraguay. Nhandipa means (term in Guarani “We have reached the end”). It was the first combat on Brazilian soil, during the famous Retirada da Laguna. The stone monument honors those killed in the battles.

9. Projeto Portal – Cidade de Zigurates (Portal Project – Zigurate´s city) – Corguinho/MS: Ziggurats were stepped constructions present among the cultures of the Sumerian and Babylonian peoples, as well as among several other civilizations around the world. It refers to one of the areas of study of the Dakila Ecosystem, which is researching ancient peoples, civilizations that held extremely advanced knowledge for their time and left a legacy that is still present in several areas of our current knowledge, having, including expeditions to different places around the world to discover, collect data and rescue that knowledge that was left behind and ended up being lost in time. In the early 1990s, Urandir and a group of pioneers began to realize the need to put the information they were discovering into practice, and felt the need to build a place that represented the purpose of the work they were doing and would still do. and in 1997 the city began to be built.

10. Morro do Paxixi (Paxixi´s Hill) – Aquidauana/MS: Located about 150 kilometers from Campo Grande, in the district of Camisão with an altitude of 700 meters, it is a popular destination for those seeking adventure and contact with nature. Before the arrival of European settlers in the region, the hill was already a sacred place for the indigenous people of the region. Legend has it that the name “Paxixi” comes from Tupi-Guarani and means “the hill that cries”. According to indigenous tradition, the hill is a sacred place where the gods cry, and the tears form the sources of the rivers that flow through the region. With the arrival of Europeans, the hill became a reference point in the region and was used as an observation post for military troops. During the Paraguayan War, Morro do Paxixi was an important strategic point for Brazilian and Paraguayan troops.

11. Mirante Morraria do Sul - Kadiwéu - In the region of the Kadiwéu Indigenous land, there are limestone outcrops from the Bocaina Formation showing stromatolites and tubular structures in an “egg-crate” pattern, deposited on the Paleoproterozoic basement, represented by schists and quartzites from the Alto Tererê Group, probable remnants of oceanic crust.

From this point you have a privileged view of the Nabileque Pantanal and the Campo dos Índios Kadiwéu.

11 ships, and plenty of ammunition surrounded the fort. The Brazilians, with 149 men, resisted until the second day when a soldier displayed the image of the Saint on the fort's wall, and the enemies ceased fire, allowing the survivors to escape.

12. Morrinho ou Toroari - Community located around "Morro de Santo Antônio", Santo Antonio do Levenger/MT. The word Toroari means hawk hill in the Bororo language and is part of indigenous mythology. It would be where the indigenous people of the Bororo nation lived. A sacred place. "Toari" it is evoked in sacred songs at funerals and in all the rituals of these people.

13. Morro do Cambambe (Cambambe´s Hill) – Água Fria/MT: The geosite is located in the place where rocks that belong to the Cachoeira do Bom Jardim Formation of the Ribeirão Boiadeiro Group emerge. In the fossiliferous levels of the rocks, semi-articulated bones or bone fragments occur, with well-preserved whole or semi-articulated skeletal pieces and fossil fragments distributed randomly, indicating different moments of burial, reworking and redeposition.

14. Morro do Japão (Japan´s Hill)- Chapada dos Guimarães/MT: Japan Hill - a mountain considered sacred by Buddhism, where eastern traditions believe that, when going around completely, a moment of connection with the divine is established, but the local community believes that at the top of the hill there is a lake, where There lives a golden fish, others say that on the sign of that hill there is a golden ox, but what you see are the lights at night that come from it to the top.

15. Morro Só (Só Hill) – Chapada dos Guimarães/MT: no information available on the internet. Site collected in previous research.

16. Templo dos Pliares (Temple of Pillars) – Alcinópolis/MS: with 100 hectares, this is a

Conservation Unit full of traces of ancient inhabitants that, according to recent studies, date back up to 10,735 years ago. At the site, visitors find engravings and paintings on walls, ceilings, and pillars of unique rock formations in the entire state. The park is located within another Conservation Unit, the Serra do Bom Jardim Natural Monument.

17. Santa Elina - Jangada/MT: The Santa Elina Shelter is a rocky archaeological site located in the Serra das Araras.

18. Morro de Santo Antônio (Santo Antônio Hill) - Santo Antônio de Leverger/MT: The hill is only 30 km from the capital. Morro de Santo Antônio is part of the imagination of the people of the Cuiabá lowlands in many different ways. It is in the center of the coat of arms of Mato Grosso, painted yellow and symbolizing the state's gold wealth. Moreover, its strategic position in relation to the Cuiabá River ensured the capital's safety during the Paraguayan War. Currently, the region is a place of great pilgrimage for religious and adventurous people.Within the mythology of this ethnic group, the hill is called Toroari, which means hawk hill. In the story there was a village where the ancestors of the Bororo´s indigenous group lived in the hill region (Morrinho ou Toroari community After a flood, only one indigenous survived the disaster by climbing to the top of the hill. Being the only survivor, would have procreated with a female deer and given rise to the Bororo´s nation. Um lugar sagrado.

19. Morro de São Jerônimo (São Jeronimo´s Hill) – Chapada dos Guimarães/MT: The hill is located on the southern edge of the Chapada dos Guimarães National Park, with a wide 360º view of the entire Pantanal plain, Morro do Quebra Gamela and Chapada walls. It is one of the highest points in the region, more than 800 meters above sea level. Furthermore, it is a "testimony hill", as geologists call it: a formation that has resisted the ravages of time and forms a gigantic massif, as if it were an island. At the top of the hill you can find small rocks that are very rich in iron ore. Legends and beliefs revolve around it. Many say that there is a

landing point for flying saucers. Others claim that the Hill is populated by elves and gnomes. Even the origin of its name, linked to the prayers made by the bandeirantes to Santa Bárbara and São Jerônimo, to calm the storms that, through that hill, fired lightning and thunder, is accompanied by mysteries, scares and fears.

20. Cidade de Pedra (Stone City) - Chapada dos Guimarães/MT: Part of the Chapada dos Guimarães National Park/Mato Grosso. The place is sacred to the Paresi-Haliti, an indigenous ethnicity, it is known by the indigenous people as the "land of the dead", because they believe that the souls of their ancestors are trapped in the rocks. The Stone House is a sandstone cave sculpted by the Independência stream. The park was created on April 12, 1989, by Decree Law 97.656. With 32,630 hectares, it protects significant samples of local ecosystems and ensures the preservation of existing natural resources and archaeological sites, providing adequate use for visitation, education, and research. Chapada dos Guimarães is part of the geological domain of sedimentary rocks in the northern Paraná Basin, within the Rio Ivaí Group. The region was formed between 460 and 420 million years ago, involving the end of the Ordovician Period and the beginning of the Silurian Period (Borghi & Moreira, 2002).

21. Jarudoré - Poxoréu/MT: Bororo Indigenous land.

22. Refúgio de Vida Silvestre Jamacá das Araras (Jamacá das Araras Wildlife Refuge) – Chapada dos Guimarães/MT: A forest protected since 1981, in a private area, a mystical area nestled in the middle of Chapada.

23. Lapa do Frei Canuto – Chapada dos Guimarães/MT.Prehistoric site with cave paintings.

24. Serra Ponta do Morro (Ponta do Morro Mountain Range) - Província Serrana/Cáceres/MT: A tourist destination with abundant natural wealth, beautiful landscapes, and an environmental preservation area that should be protected by all, as it is part of our state's Natural Heritage.

25. Morro da mesa (Table´s Hill)– Chapada dos Guimarães/MT: no information available on

the internet. Site collected in previous research.

26. Cachoeira do Quilombo Furnas do Dionísio (Waterfall) – Quilombo Furnas do Dionísio - Jaraguari/MS: Has a history with the waters from the waterfall, formerly considered that the water could be sacred, bringing rain when taken to "Nossa Senhora da Aparecida", a saint on top of the hill and formerly and currently acting as a place for offerings from African-based religions.

27-31. Cemitério Guató/Ribeirinhos (Guato´s Cemitery): Areas considered sacred for the traditional and indigenous people living in the Amolar region in Pantanal.

32. Cachoeira da Antiga Ferroviária (Antiga Ferroviária Waterfall) - Corumbá/MS: Waterfall used by African-based religions in Corumbá - Maria Coelho settlement - São Domingos region.

33. Baiá Chacororé (Chacororé´s Bay): Pantanal, in Barão de Melgaço - 110 km from the capital of Mato Grosso. The third largest bay in the biome, Chacororé has a unique formation. On one side, there are 14 narrow channels, called "corixos," that connect the Cuiabá River to the bay. On the other side, water comes from two streams: Cupim and Água Branca, which originate in the plateau and descend through the hills to the bay. This system is unique in the biome. In the imagination of the Pantanal population, there are submerged and supernatural worlds interspersed with the natural world, populated by mythical and enchanted beings.

34. Morro Santa Cruz (Santa Cruz´s Hill) – Corumbá/MS: found in 1870 by a explorer called Mauricio Alves de Arruda. When Maurício went up to explore the Morro, he noticed signs that other people had already passed through there before, probably at the time of the Paraguayan War. Up there he also found a cross that, for many, was a sign of death. But he didn't think so. It was a sign of life, of union, of the presence of Jesus. It was then that he named that place Morro de Santa Cruz and placed his faith. The celebration is maintained to this day by his descendants.

35. Pixaim - culto às águas (Pixaim River)- Poconé/MT: a river at Transpantaneira (MT-060) that used to flood trought Rio Claro River until Bento Gomes´s river.

36. Forte Coimbra - Nossa Senhora do Carmo (Coimbra Fort)- Corumbá/MS - For over two centuries, the celebration of the Fort's patron saint's day cultivates faith and keeps alive accounts that prove the manifestations of the Saint in two decisive episodes for guaranteeing Brazilian sovereignty in that locality. Coimbra Fort was built in 1775, on the banks of the Paraguay River, located between hills, just above where the triple border mark exists - Brazil, Paraguay, and Bolivia - between the Pantanal of Corumbá and Porto Murtinho. Its construction, at a time of total fragility of Portugal's borders with Spain, generated controversy, as it was built in the wrong place. The chosen point was Fecho dos Morros, already near Murtinho. Our Lady of Carmel is credited with miracles that occurred during battles against the Spanish and Paraguayans in 1801 and 1864, respectively. In the first battle, the Saint is said to have saved the Fort's military garrison, which had 110 men, five canoes, and three cannons, from a massacre on September 17, 1801, when the Spanish army of 600 men, ships, and 30 cannons had orders to occupy the place in the dispute for territory with Portugal. After nine days of battle, the Spanish won but retreated when they saw the image of the Saint at the entrance of the Fort. The second manifestation occurred during the Paraguayan War. On December 28, 1864, the Paraguayan troop with 3,200 men, 41 cannons, 11 ships, and plenty of ammunition surrounded the fort. The Brazilians, with 149 men, resisted until the second day when a soldier displayed the image of the Saint on the fort's wall, and the enemies ceased fire, allowing the survivors to escape.

37. Gruta Ricardo Franco - Águas Milagrosas (Ricardo´s Franco Cave - Miraculous Waters) – Corumbá/MS: Located three kilometers from the Fort, at the end of a long trail, the Ricardo Franco cave is one of the oldest registered in Brazil. Related to the miracles of the Saint at Coimbra Fort, many graces are attributed to Our Lady of Carmel, to whom miraculous powers are also attributed in the waters inside the Ricardo Franco grotto, the third largest in the state, where a stalagmite is observed as resembling the figure of the saint. Although science considers the crystalline waters contaminated by the feces of the bats that inhabit it, the

population believes that miraculous powers reside in the liquid. The visit to the grotto, 8 km from the fortification, is part of the ritual of celebrating the Saint on July 16th.

38. Morro do Cruzeiro - Cristo Rei do Pantanal/ via sacra (Cruzeiro´s Hill - Christ the King of Pantanal/ way of the cross) – Corumbá/MS: the Cristo Rei do Pantanal complex is made up of 72 statues, 71 representing the Via Sacra (each statue is, on average, 2 m high) and the statue of Cristo Rei do Pantanal (12 m high). The route to get to Cristo Rei is also an attraction in itself. Along the way, sculptures by Izulina Xavier represent the 14 stations of the Passion of Christ.

39. . Cemitério Guató/Ribeirinhos (Guato´s Cemitery): Areas considered sacred for the traditional and indigenous people living in the Amolar region in Pantanal.

40. Crosta laterítica - inscrições rupestres (Lateritic Crust - Rock Inscriptions) -Corumbá/MT: Fazenda Figueirinha, 27 km from the urban area, next to BR 262. Coordinates: 57038'47"W - 19014'09"S. Lateritic crust on petromitic ferruginous conglomerates of the Urucum Formation, with inscriptions in low relief of concentric circles, circumferences, spirals, sinuous lines, and tridactyls, extending for hundreds of meters. The presence of plant elements typical of the Caatinga (a biome characteristic of the Brazilian semi-arid region in the Northeast of the country) and the border region stands out in the phytogeographic landscape. Archaeological research indicates the presence of groups of pre-ceramic hunter-gatherers about 2,000-3,000 years ago.

41. Crosta laterítica - inscrições rupestres (Lateritic Crust - Rock Inscriptions) – Corumbá/MS: 20 km from the urban area, next to the Estrada Parque. Coordinates: 57033'32"W - 19009'57"S. Archaeological site MS CP 03 ("Archaeology Lookout") - Like the previous site, it is a lateritic crust on petromitic ferruginous conglomerate with inscriptions in low relief, but located on the opposite side of Morro Santa Cruz.

42. Pedra Baía Mandioré (Rock Bay Mandioré): bordering Bolivia, the Mandioré lagoon is

limited throughout its eastern portion by the Paraguay River and the region called Pantanal Uberaba-Mandioré. In addition to the Amolar elevations, there is a predominance of Pantanal waters, with streams, ebbs and bays, and the Paraguay River.

43. Morro Pelado (Naked Hill) – Cáceres/MT: The informants mentioned Morro Pelado as the most cited location, with 12 mentions by boat-hotel captains and 9 by pilots, highlighting its significance as one of the most visited sites by tourists in Cáceres, Mato Grosso. Many people climb up the hill, they say it holds a lot of history. It’s best to climb when the sun is hot. People go up there often because there’s a chapel at the top, with an image of Nossa Senhora Aparecida. Devotees climb up to pray, make requests, take photos from the top, and ask for a good journey for everyone. That was built by a woman, a devotee from Minas Gerais, who placed it there and fulfilled a promise she had made."

44. Morro do Padre (Father’s Hill) – Rio Verde/MS: One day, the owner of a farm asked a priest to perform a wedding in the region. During the ceremony, the priest spotted the hill. When he told the farmer that he had dreamed of the place his entire life, the farmer quickly tried to discourage him. The farmer said it would be impossible to climb the hill because the forest was too dense. However, he promised the priest that if he managed to climb it, the hill would be his. After studying the best way to reach the top, the priest acquired railroad tracks and began his work. He would dig into the hill’s wall, place a track, and dig again. He built a handrail to climb to the top and installed an iron mesh under the steps for added safety. The results of this work remain intact to this day. At the top of the staircase is an iron gate with a giant padlock, for which only Friar Davi, the current guardian (as of early 2019), holds the key. At the summit, there is a dormitory, a chapel, and a system with 12 water tanks. It is said that religious figures would spend days up there.

45. Morro do CaraCara (Caracara Hill) – Pantanal Matogrossense National Park/MS: An archaeological site that traces the history of the Xarayes Sea and the first inhabitants of the

Pantanal during prehistoric and colonial times.

46. Monumento Marco Zero – Kadiwéu (Monument Zero Point)- Kadiwéu, Indigenous Land/MS: Recognized as national historical and artistic heritage, based on the list of assets selected and listed by Iphan (National Institute of Historical and Artistic Heritage), resulting from an institutional historical process, these assets possess monumental and exceptional characteristics, being linked to memorable events in Brazil's history. The concept of Brazilian cultural heritage encompasses tangible and intangible assets, considered individually or collectively, that serve as references to the identity, actions, and memory of the diverse groups that form society.

47. Ilha Ínsua (Ínsua Island)/MS: Sacred to the Guató people, this area is part of the history of territorial delimitation and a site for marriage ceremonies. The Guató occupation area lies entirely within the Pantanal region, mostly in Brazilian territory in the states of Mato Grosso and Mato Grosso do Sul, with a portion extending into Bolivian lands. Key areas occupied by this people include the following: the main course of the Paraguay River, the Paraguay-Mirim River, Alegre River, Caracará region, São Lourenço River, part of the Cuiabá River, Dom Pedro II Canal, Uberaba and Gaíva Lagoons, Morraria dos Dourados, Serra do Amolar, and Ínsua Island. Currently, there are three Guató nuclei, one located in Mato Grosso do Sul (Uberaba Village, Ínsua Island) and two in Mato Grosso, in the municipalities of Barão de Melgaço and Poconé. In these areas lies the Baía dos Guató Indigenous Land (Aterradinho do Bananal and Aterro São Benedito villages), near the Perigara and Cuiabá Rivers. The third nucleus in Mato Grosso is near Cáceres; however, further anthropological studies are needed to identify the Guató population residing there and to delimit their occupied territory [data from 2008].

48. Comunidade Albuquerque (Albuquerque Community) – Albuquerque/MS: Guató Cemetery. A region historically occupied by the Guató people.

49. Cachoeira da Macumba (Macumba´s Waterfall) - Campo Grande/MS: very relevant area for African-based religions and the only stream around the city of Campo Grande that belongs to the Upper Paraguay Basin.

50. Baía Gaíva (Gaíva Bay)/MS: According to the Guató people, this is the site where the Pantanal originated and holds sacred significance for them. In ancient times, a Guató community lived in the area now occupied by Gaíva Lagoon, located on the border between Brazil and Bolivia. At the time, it was a dry region, not a large bay (a term used locally to refer to lakes and lagoons of all types). One day, some women went to fetch water from a spring near their homes. Upon arrival, they spotted a white cavy, a creature never before seen in the area, which they called meki in their native language. That evening, after darkness fell and the adults gathered around the fire, the women recounted what they had witnessed. A boy listened carefully and, early the next morning, went to see the creature. Armed with a bow and arrow, he shot the animal with a precise hit to the chest. Before dying, the cavy revealed it was not an ordinary animal but the guardian of the water. It warned the boy that water would gush forth from the spring, flooding almost the entire region as punishment for the cruelty inflicted in response to its generosity in providing water to quench people’s thirst. It foretold that the wicked would drown, while the good should seek refuge on the hilltops. As soon as the animal died, a massive surge of water erupted from the spring, and the ground began to shake. The roaring and bubbling of the water were deafening. In panic, everyone ran for their lives. The wicked tried to reach the hills but stumbled due to the tremors and were swept away by the flood. Many good people managed to climb to the hilltops of Ínsua Island, where they were safe. Eventually, the waters receded slightly, but the region was forever changed. The place where the community once stood became Gaíva Bay, and a watery world emerged—the Pantanal, named Guadakan in the native language. The survivors became skilled canoeists and continued to live in the area. They soon learned from the mythological

Matchubé people how to construct artificial mounds (marabohó) using soil and other materials. In return, the Guató taught them how to build and use dugout canoes crafted from tree trunks. The elders learned and passed down the belief that everything in the Pantanal has a guardian: rivers, bays, hills, corixos (water channels connecting waterways), plants, fish, and other animals. These guardians are non-human, supernatural, or divine beings that demand respect and ethical behavior from canoeists so that all can live in harmony with the resources they provide. When rules are broken—such as navigating the Gaíva waters without silence or hunting and fishing more than needed for survival—punishments ensue.

This cosmology was shared by Francolina Rondon, known as Dona Negrinha, a Guató woman born in the 1910s who passed away in 2000. Her account reveals that the history of the original peoples of the Pantanal—or Guadakan, also called Chaco in Quechua and Êxiva in the Terena language—did not begin in 1492 or 1500. It is marked by complex trajectories that date back at least 8,400 years and may extend even further, between 10,000 and 11,000 years ago, when the plain began to take on ecological features similar to those seen today.