GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 14, n. 92, 2026

Green and Blue Infrastructure: Possibilities and Reflections on the Barbado Stream in Cuiabá-MT

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Submissão / Submission: 29/11/2025
Aceito / Acceptance: 15/05/2026
PAIVA, Fabio Friol Guedes de; PAULA, Diana Carolina Jesus de; SOUZA, Natallia Sanches e; GULINELLI, Erica Lemos. Infraestrutura Verde e Azul: Possibilidades e Reflexões no Córrego do Barbado em Cuiabá-MT. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 14, n. 92, p. e2552, 2026.
DOI: 10.17271/23188472149220266395. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/6395.

GC Revista Nacional de Gerenciamento de Cidades
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ISSN 2318-8472, v. 14, n. 92, 2026

Infraestrutura Verde e Azul: Possibilidades e Reflexões no Córrego do Barbado em Cuiabá-MT

RESUMO

Objetivo - Analisar as áreas de risco de inundação no córrego do Barbado (Cuiabá-MT) e realizar um estudo de viabilidade com soluções de infraestrutura verde e azul para adaptação nessas áreas.

Metodologia - Foram examinados o relatório da Defesa Civil Nacional e a projeção de risco do Serviço Geológico do Brasil. Também foram consultados documentos técnicos municipais e literatura especializada sobre infraestrutura verde e drenagem sustentável, adotando abordagem diagnóstica e revisão técnica.

Originalidade/relevância - O estudo aborda um gap relacionado à escassez de análises integradas entre risco de inundação, urbanização irregular e soluções baseadas na natureza em cidades brasileiras de clima tropical. Contribui para o debate sobre resiliência urbana e gestão sustentável de bacias hidrográficas urbanas.

Resultados - Dois trechos do córrego do Barbado foram identificados com alto risco de inundação e deslizamento. Observou-se a viabilidade de inserção de soluções de infraestrutura verde e azul nas avenidas principais e a implantação de um parque linear com técnicas de bioengenharia para estabilização das margens.

Contribuições teóricas/metodológicas - O estudo reforça a importância da articulação entre diagnóstico de risco hidrológico e soluções de infraestrutura verde e azul, demonstrando a viabilidade de intervenções em áreas urbanas vulneráveis.

Contribuições sociais e ambientais – O estudo de viabilidade evidencia a redução das vulnerabilidades e promove restauração ecológica, aumento da permeabilidade do solo e qualificação dos espaços públicos.

PALAVRAS–CHAVE: Córregos urbanos. Resiliência urbana. Soluções baseadas na natureza.

Green and Blue Infrastructure: Possibilities and Reflections on the Barbado Stream in Cuiabá-MT

ABSTRACT

Objective - To analyze the flood risk areas in the Barbado stream (Cuiabá-MT) and conduct a feasibility study with green and blue infrastructure solutions for adaptation in these areas.

Methodology - The report from the National Civil Defense and the risk projection from the Geological Survey of Brazil were examined. Municipal technical documents and specialized literature on green infrastructure and sustainable drainage were also consulted, adopting a diagnostic approach and technical review.

Originality/relevance - The study addresses a gap related to the scarcity of integrated analyses between flood risk, irregular urbanization, and nature-based solutions in Brazilian cities with tropical climates. It contributes to the debate on urban resilience and sustainable management of urban watersheds.

Results - Two sections of the Barbado stream were identified as having a high risk of flooding and landslides. The feasibility of incorporating green and blue infrastructure solutions on the main avenues and implementing a linear park with bioengineering techniques for bank stabilization was observed.

Theoretical/methodological contributions - The study reinforces the importance of linking hydrological risk diagnosis with green and blue infrastructure solutions, demonstrating the feasibility of interventions in vulnerable urban areas.

Social and environmental contributions – The feasibility study highlights the reduction of vulnerabilities and promotes ecological restoration, increased soil permeability, and improved public spaces.

KEYWORDS: Urban streams. Urban resilience. Nature-based solutions.

Infraestructura Verde y Azul: Posibilidades y Reflexiones sobre el Arroyo Barbado en Cuiabá-MT

RESUMEN

Objetivo: Analizar las zonas de riesgo de inundación en el arroyo Barbado (Cuiabá-MT) y realizar un estudio de viabilidad con soluciones de infraestructura verde y azul para la adaptación en estas zonas.

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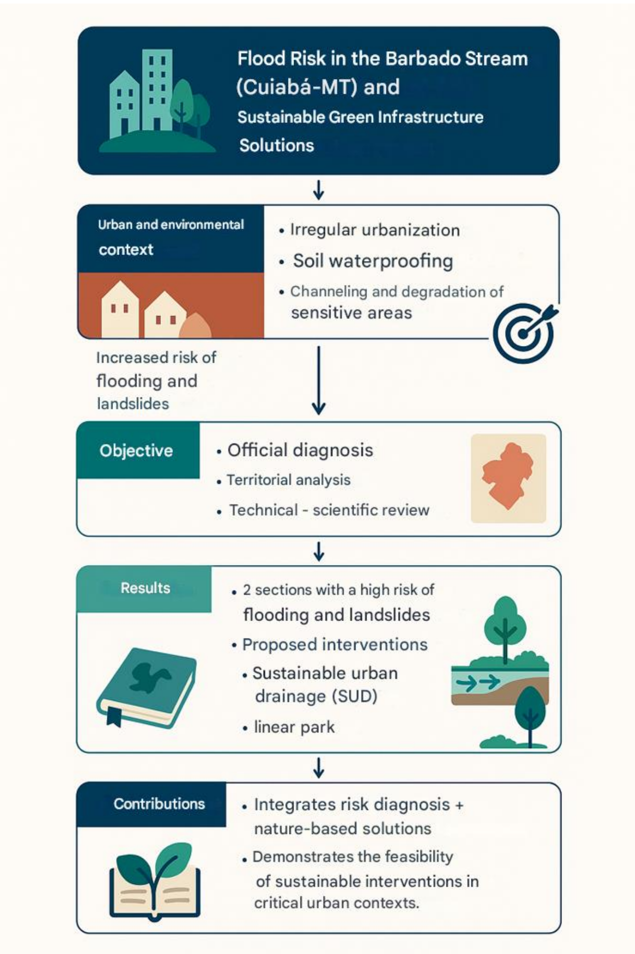
Metodología: Se examinó el informe de la Defensa Civil Nacional y la proyección de riesgo del Servicio Geológico de Brasil. También se consultaron documentos técnicos municipales y literatura especializada sobre infraestructura verde y drenaje sostenible, adoptando un enfoque de diagnóstico y revisión técnica.
Originalidad/relevancia: El estudio aborda una brecha relacionada con la escasez de análisis integrados entre el riesgo de inundación, la urbanización irregular y las soluciones basadas en la naturaleza en las ciudades brasileñas con climas tropicales. Contribuye al debate sobre la resiliencia urbana y la gestión sostenible de las cuencas hidrográficas urbanas.
Resultados: Se identificaron dos tramos del arroyo Barbado con alto riesgo de inundaciones y deslizamientos. Se observó la viabilidad de incorporar soluciones de infraestructura verde y azul en las avenidas principales e implementar un parque lineal con técnicas de bioingeniería para la estabilización de riberas.
Contribuciones teóricas y metodológicas: El estudio refuerza la importancia de vincular el diagnóstico de riesgos hidrológicos con soluciones de infraestructura verde y azul, demostrando la viabilidad de las intervenciones en zonas urbanas vulnerables.
Contribuciones sociales y ambientales: El estudio de viabilidad destaca la reducción de vulnerabilidades y promueve la restauración ecológica, el aumento de la permeabilidad del suelo y la mejora de los espacios públicos.

PALABRAS CLAVE: Arroyos urbanos. Resiliencia urbana. Soluciones basadas en la naturaleza.

GRAPHICAL ABSTRACT



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1 INTRODUCTION

In recent decades, the occurrence of extreme climate events has become increasingly frequent. However, a large share of Brazilian cities was not planned to cope with droughts, heat waves, floods, and inundation events, triggering a true "domino effect" of urban problems (Britto; Pessoa, 2023; Rosso *et al.*, 2023).

Brazil, located in the tropical zone, is frequently affected by intense rainfall, which often results in floods, inundations, and landslides. According to the Ministry of Integration and Regional Development (BRAZIL, 2023), notable events include the flooding of the Guaíba River (1941), landslides in the Serra das Araras (1967), and in the mountainous region of Rio de Janeiro (2011), the latter resulting in more than 947 deaths and 300 missing persons. In 2024, the state of Rio Grande do Sul experienced another major disaster, with 183 fatalities and more than 600,000 people displaced or left homeless.

Between 1991 and 2023, the Atlas recorded 25.94 thousand hydrological events, of which 74% were related to intense rainfall, resulting in 3,464 deaths and economic losses exceeding R$151 billion. These figures highlight the fragility of urban infrastructure and the lack of effective stormwater drainage and management policies, whose integration into sanitation planning is essential to reduce the magnitude and recurrent impacts of such disasters.

Infrastructure can be understood as the set of essential services that support the socioeconomic development of a region, including sanitation, transportation, energy, and telecommunications. Drainage systems comprise the infrastructure responsible for the collection, conveyance, and final discharge of surface runoff. Stormwater management, in turn, encompasses the measures aimed at minimizing damage and risks to which the population is exposed and should be conceived at the watershed scale, which is composed of multiple sub-watersheds. Together, these elements constitute urban macrodrainage and microdrainage systems (Miguez; Veról; Rezende, 2015).

Furthermore, macrodrainage systems regulate the volumes of water conveyed by major watercourses, ensuring the protection of urban and rural areas against flooding in rivers and streams. They are composed of large-scale structures designed to control hydrological flows across different territorial contexts, such as dams, levees, channelized reaches, and large-capacity conduits and galleries. Microdrainage systems, in contrast, collect and convey runoff from individual lots, streets, and public spaces; their layout is essentially defined by the urban street network. They are characterized by smaller-scale but essential works, including pavements incorporating drainage devices such as curbs, gutters, storm inlets, and catch basins, among others (Miguez; Veról; Rezende, 2015).

Therefore, rapid urban growt and often disorderly, has led to the collapse of urban systems and to the breakdown of the once integrated relationship between rivers and cities (Corrêa; Vazquez; Vanzela, 2018). In this context, the role of the road-oriented urban planning model stands out, as it has been widely disseminated throughout Brazil, including in Cuiabá,

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Mato Grosso. This model, based on road hierarchy and the prioritization of individual motorized mobility, has guided urban expansion according to the logic of major roadways, fostering increasing distances between housing, employment, and services. As a result, cities have become progressively more dispersed, with greater automobile dependence, higher travel costs, and increased pressure on environmentally sensitive peripheral areas.

In Cuiabá, the siting of housing developments at the edges of the urban perimeter, combined with associated socio-spatial segregation, results in lengthy public transport commutes, reaching 62–90 minutes to the city center, thereby reinforcing the trend toward informal occupation of fragile areas vulnerable to environmental risks (Azevedo *et al.*, 2019). Consequently, the occupation of permanent preservation areas (PPAs) represents one of the most critical expressions of this problem.

It is estimated that more than one million people live in such areas in Brazil, despite the stringent legal framework aimed at environmental protection. However, legislation has proven insufficient to curb occupation, which predominantly concentrates low-income groups excluded from the formal land market and from access to adequate infrastructure (Freiria *et al.*, 2009). As a result, socioeconomic factors compound environmental fragility, further intensifying urban vulnerability.

In parallel, the predominance of so-called gray infrastructure, paved streets, piped water and sewer networks, and, above all, the straightening, channelization, and covering of watercourses to enable new roadways, has intensified urban imperviousness (Mascaró; Mascaró, 2009). This type of intervention has led to the removal of riparian vegetation, accelerating surface runoff and exacerbating flooding and inundation problems.

To reverse this situation and restore the relationship between cities and nature, it is essential to incorporate green and blue infrastructure, which helps increase soil permeability, slow surface runoff, mitigate urban heat islands, and improve environmental quality. Green and Blue Infrastructure (GBI) refers to the set of natural elements present within cities, including green areas and water systems, when integrated, perform environmental, hydraulic, landscape, and social functions. When articulated as a network, these infrastructures contribute to the conservation of ecosystem processes, promoting benefits for both the natural environment and the urban system, while also generating significant social gains (SÃO PAULO, 2022). Key elements that can be integrated include rain gardens, tree-lined streets, green corridors, floodable parks, retention basins, and bioswales, among other devices.

One example is the rain garden (Fig. 1a), implemented in shallow depressions composed of filtering layers, native vegetation, and, when necessary, granular storage reservoirs (Woods-Ballard *et al.*, 2007). These structures reduce the need for irrigation and contribute to pollutant filtration, especially when combined with bioswales (Fig. 1b), which rely on the combined action of soil, vegetation, and microorganisms (Cormier; Pellegrino, 2008).

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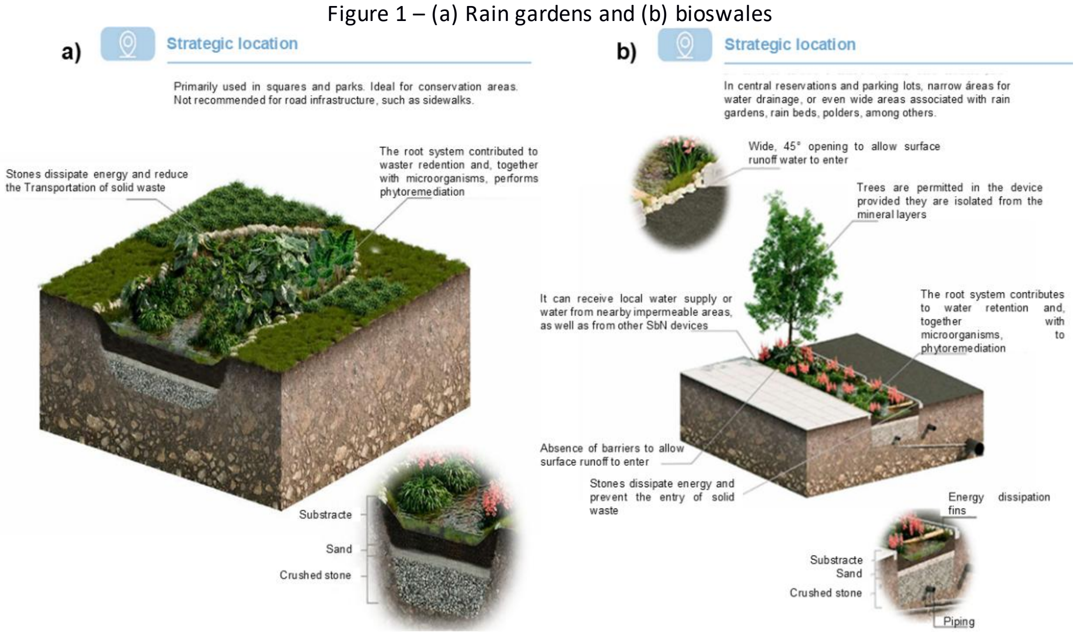
Figure 1 – (a) Rain gardens and (b) bioswales



Source: GAP FUND INITIATIVE, 2023. Adapted and translated by the authors.

Floodable parks (the blue component) constitute another promising solution. They function as naturalized retention basins (Fig. 2a), capable of controlling flooding while simultaneously providing recreational public spaces and productive ecosystems. Examples such as the Qunli Wetland Park in China demonstrate the potential of these structures to integrate water management, biodiversity, and urban quality of life (Palazzo, 2019). Linear parks (Fig. 2b), implemented along rivers, streams, or channels, combine riparian vegetation (green component) with the dynamics of flowing waters within channels or across floodplains (blue component), forming multifunctional spaces for environmental conservation, leisure, and flood protection (SÃO PAULO, 2022).

Figure 2 – (a) Retention basin and (b) Linear park

a)

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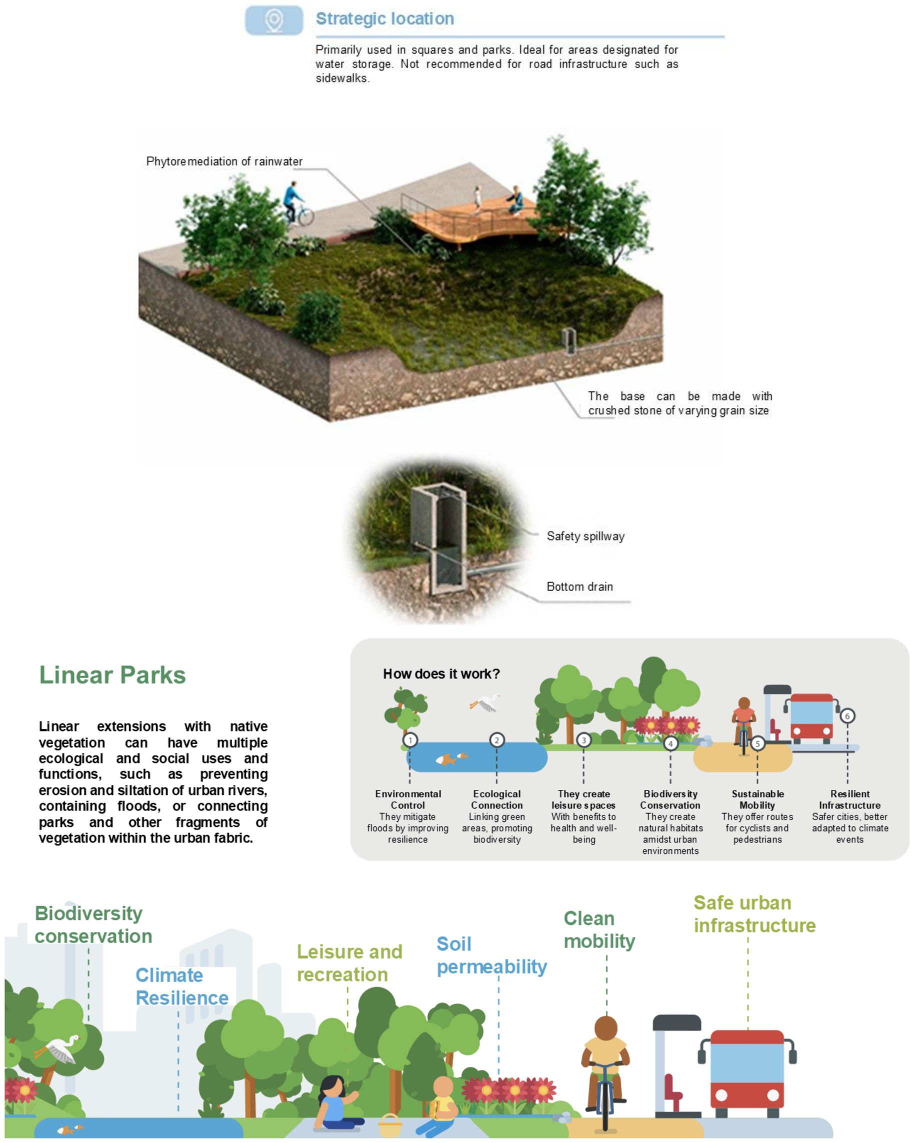

Source: GAP FUND INITIATIVE, 2023; BOTICÁRIO GROUP FOUNDATION, 2024.
Adapted by the authors.

Urban tree cover (green component), in turn, plays a fundamental role in mitigating urban heat islands and reducing surface runoff. Increased imperviousness and the reduction of vegetated areas are directly associated with higher air and surface temperatures (Masiero; Souza, 2019; Paula *et al.,* 2024).

Another strategic element is permeable pavement, which enhances stormwater infiltration. Considering that between 20% and 40% of urban surfaces are paved (Wang *et al.*, 2019), the mitigation potential is substantial. In Brazil, the interlocking drainage pavement is widely used, with specific legislation that regulates its application, according to Complementary Law No. 11,509 (SÃO PAULO, 1994) and Complementary Law No. 516 (CUIABÁ, 2022). Studies indicate that replacing conventional pavements with porous pavements can reduce runoff volumes by up to 60% during storm events, in addition to significantly lowering peak flows (Liu; Chen; Peng, 2014).

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In a climatically harsh context such as Cuiabá, the implementation of areas with high tree density aimed at microclimate mitigation could promote pedestrian and bicycle circulation in shaded, pleasant, and safe environments. The suppression of dense vegetation will lead to an increase in air temperature as a result of surface warming caused by the reduction of tree-covered areas that promote moist heat exchanges; that is, through changes in building typologies associated with heat-storing materials (Paula *et al.*, 2025; Souza *et al.*, 2024).

However, it is important to emphasize that the effectiveness of green and blue infrastructure also depends on adequate soil conditions. Soil compaction, for instance, drastically reduces infiltration capacity, underscoring the importance of appropriate implementation methodologies to promote more resilient cities capable of adapting to extreme climate events.

As already emphasized by Rogers (2001), living in urban environments should not pose a risk to the very survival of civilization; on the contrary, future cities have the potential to act as catalysts for restoring the balance between humanity and nature. It therefore becomes evident that cities must be “rethought” from a perspective that prioritizes sustainable urban solutions and more resilient water management.

In light of this context, the present article aims to evaluate and propose a feasibility study for the adoption of green and blue infrastructure solutions in two segments of the Barbado Stream, identified as risk areas by the Geological Survey of Brazil (SGB, 2024). The stream, located in Cuiabá, Mato Grosso, is one of the main left-bank tributaries of the Cuiabá River and represents a strategic environmental system for the city’s hydrological and urban resilience.

2 Methodology

Since the arrival of the São Paulo *bandeirantes* in the 18th century, the urbanization process of Cuiabá has been deeply linked to its watercourses. The first settlement of what was then the Vila do Senhor Bom Jesus de Cuiabá, founded in 1719, emerged precisely along the banks of the Prainha Stream (CUIABÁ, 2008). The river that gave the city its name also played a central role over the centuries, being used for irrigation, fishing, and fluvial transportation.

However, this relationship began to change significantly from the 1970s onward, when the federal government promoted the occupation of Brazil’s Central-West region through the movement known as the “March to the West.” This cycle of urban growth intensified pressure on water bodies, reshaping the city’s socio-environmental dynamics (Nora, 2019).

In this context, Menezes Filho and Amaral (2014) observed that the main occurrences of floods and inundations within Cuiabá’s urban perimeter between 1970 and 2010 coincide with the period of greatest population growth, the occupation of stream margins, and the channelization of several watercourses, most notably the Barbado Stream.

The Barbado Stream microbasin (Fig. 3), one of the 24 streams that make up Cuiabá’s urban hydrographic network, covers an area of 13.89 km² and exhibits a high degree of urbanization, with approximately 57.4% of its area impervious and showing a growing trend (Ventura, 2011). The riparian vegetation is classified as a Permanent Preservation Area (PPA), in accordance with Municipal Complementary Law No. 004 (CUIABÁ, 1994).

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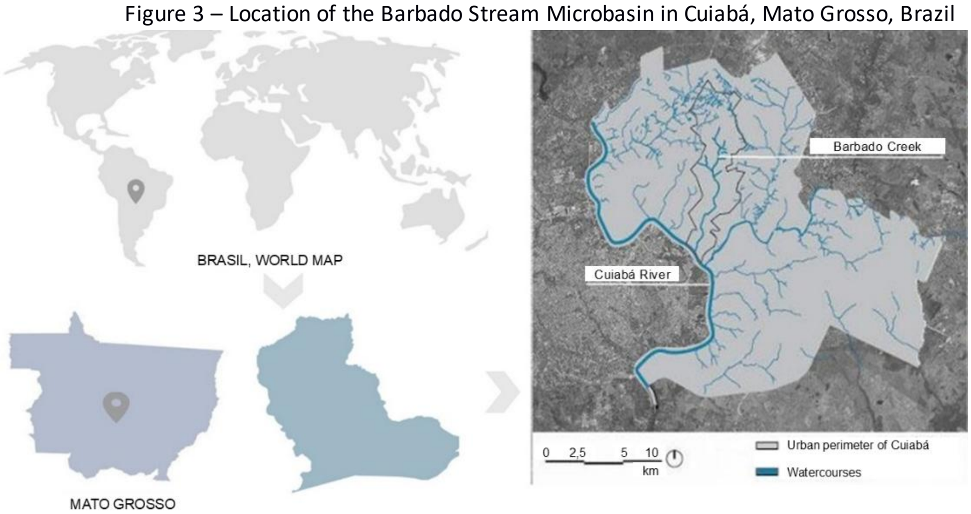
The Barbado Stream is located in the central-eastern portion of Cuiabá, extends for approximately 9,500 meters, and has undergone significant alterations due to human activities, resulting in multiple socio-environmental problems. Its headwaters are located within the Massairo Okamura Ecological Reserve, and its upper course flows through the neighborhoods of Morada do Ouro, Jardim Aclimação, Bela Vista, Terra Nova, Dom Bosco, Campo Verde, Canjica, and Bosque da Saúde. The middle course runs through the neighborhoods of Pedregal, Jardim Itália, Alphaville Condominium, Renascer, Jardim Leblon, Jardim das Américas, and Cidade Universitária (UFMT). The lower course encompasses the neighborhoods of Jardim Tropical, Jardim Petrópolis, Praieiro, and Praeirinho, discharging at Avenida Beira Rio, where it flows into the Cuiabá Rive (Silva; Takata; Rodrigues, 2016).

Figure 3 – Location of the Barbado Stream Microbasin in Cuiabá, Mato Grosso, Brazil



Source: Macedo (2017). Adapted by the authors.

As a methodological procedure, this study adopted an exploratory research approach, involving a literature review of documents, books, legislation, and scientific articles, as well as an analysis of the potential implementation of green and blue infrastructure techniques that constitute Nature-Based Solutions (NbS). Based on this approach, a feasibility study is proposed for selected segments of the Barbado Stream and surrounding areas that convey large volumes of stormwater.

According to the United Nations Environment Programme (UNEP, 2022), Nature-Based Solutions (NbS) are actions aimed at protecting, conserving, and restoring ecosystems, while

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promoting the sustainable management of natural or modified resources across terrestrial, freshwater, coastal, and marine systems. These solutions effectively and adaptively address social, economic, and environmental challenges, while simultaneously enhancing human well-being, ecosystem services, resilience, and biodiversity benefits.

It is an umbrella concept encompassing four dimensions. The strategic dimension defines long-term objectives and priority socio-environmental challenges, guiding actions tailored to the local context; it includes Ecosystem-based Adaptation (EbA) and Ecosystem-based Disaster Risk Reduction (Eco-DRR). The performance dimension assesses the effectiveness and adaptability of solutions, verifying whether they deliver the expected benefits, such as improved water quality, urban heat island mitigation, and disaster prevention, and includes Green Infrastructure (GI), Blue Infrastructure (BI), Green–Blue Infrastructure (GBI), and Urban Forests (UF). Spatial planning addresses the siting and territorial integration of NbS, considering environmental and social characteristics; it encompasses Sustainable Urban Drainage Systems (SuDS), Ecological Engineering (EE), Best Management Practices (BMPs), Low Impact Development (LID), and Water-Sensitive Urban Design (WSUD). Finally, the soft engineering dimension applies technical and interdisciplinary knowledge (engineering, architecture, ecology) to design sustainable infrastructure by integrating natural and built processes, such as river renaturalization, and includes Ecosystem Services (ES).

Moreover, Nature-Based Solutions are classified into five categories: restorative, which include ecological restoration, forest landscape restoration, and ecological engineering—such as reforestation, river rehabilitation, and regenerative agriculture; objective-based, encompassing ecosystem-based adaptation and mitigation, ecosystem-based disaster risk reduction, and climate adaptation services—addressing climate change and natural hazards; infrastructure-based, which comprise natural infrastructure and green infrastructure; management-based, including integrated coastal zone management and water resources management—aimed at improving water quality and quantity; and protection-based, which involve approaches for managing conservation areas or other conservation measures through area-based protection.

For the feasibility study, the following categories were selected: the restorative category, aimed at the requalification of the stream; the objective-based category, focused on flood risk reduction; and the infrastructure-based category, which integrates Green–Blue Infrastructure (GBI). Consequently, the study addresses the strategic dimension through Eco-DRR, the performance dimension through GBI, and the spatial planning dimension through SuDS and WSUD.

As a methodological technique for the development of this study, the following stages were carried out: research, corresponding to the understanding of local conditions; analysis, involving the transformation of data into tables, matrices, and graphs that illustrate the identified problems; diagnosis, aimed at identifying the various issues related to the intervention area; and prognosis, consisting of the proposal of potential solutions (Silva, 2019).

Accordingly, an investigation was conducted of two segments of the Barbado Stream in Cuiabá, as shown in Figure 4. These segments were delineated because they have been classified as risk areas by the National Civil Defense (BRAZIL, 2014) and by the Geological Survey of Brazil (SGB, 2024), thus requiring the implementation of technical drainage solutions to

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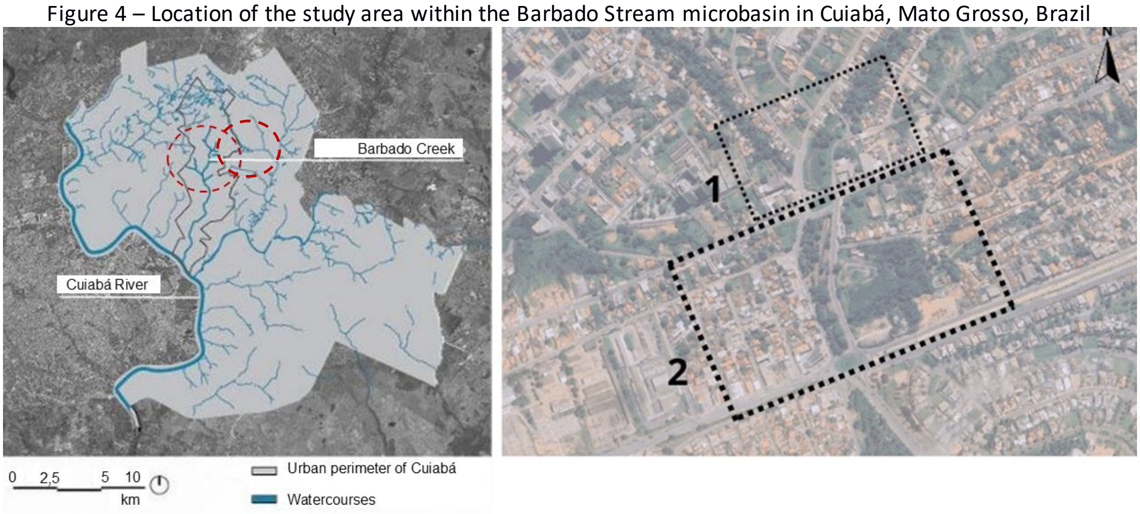
mitigate future disasters. The analyzed segments correspond to the upper course of the Barbado Stream and encompass four neighborhoods: Campo Verde, Bosque da Saúde, Dom Bosco, and Canjica.

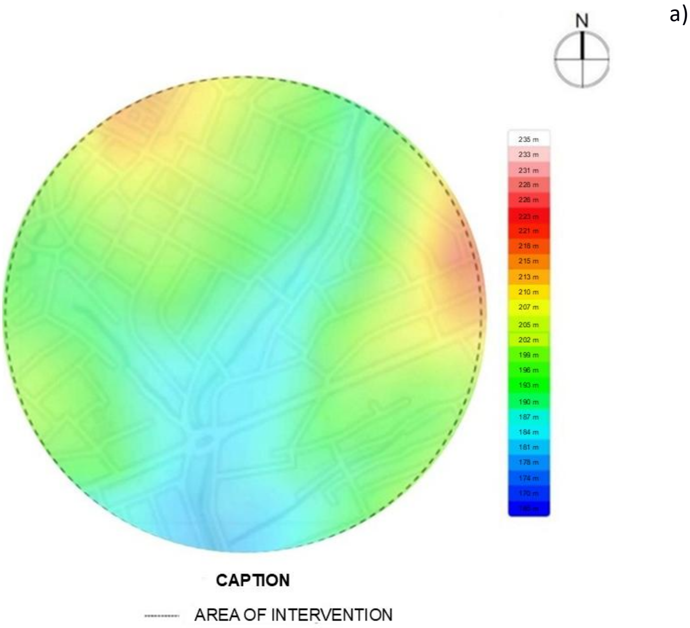
Figure 4 – Location of the study area within the Barbado Stream microbasin in Cuiabá, Mato Grosso, Brazil



Source: Google Earth (2024); Macedo (2017). Adapted by the authors.

In this way, using satellite images obtained from Google Earth Pro, it was possible to conduct an analysis of the intervention area based on its biophysical support (topography, hydrography, and vegetation), as shown in Figure 5.

Figure 5 – Diagnosis of the biophysical support of the selected segments: (a) topography, (b) hydrography, and (c) vegetation



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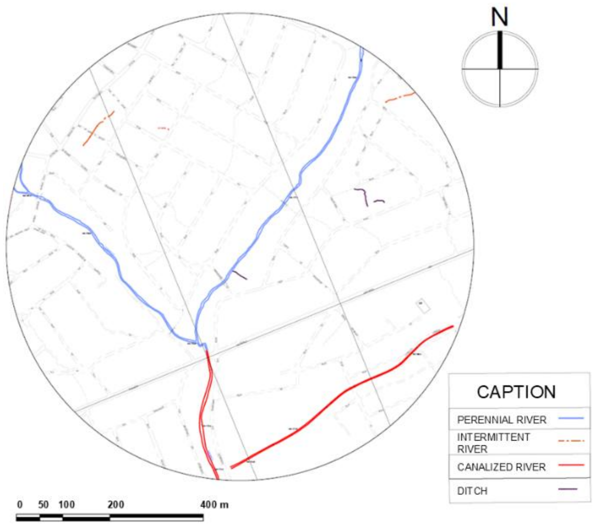
b)



c)

Source: Prepared by the authors (2025)

The intervention area presents gently undulating topography, characterized primarily by the 210-meter contour line, indicating a slope from the Campo Verde neighborhood toward Dom Bosco. Based on the hydrographic map of the intervention area, it is possible to analyze the course of the Barbado Stream, as well as to observe that two intermittent streams are also present within the intervention area.

The Barbado Stream extends for a total length of approximately 9.4 km, of which 4.7 km are open-channelized, with its Permanent Preservation Area (PPA) encroached upon by streets and avenues. Originally, the sub-basin was fed by several small springs, many of which have now been extinguished. Three springs remain active, located within the Massairo Okamura Park, in the Canjica neighborhood, and near the Political–Administrative Center. The original characteristic vegetation corresponds to arboreal savanna (cerrado), composed of twisted trees and small trees interspersed with a woody grass layer, associated with other herbaceous species, subshrubs, and low shrubs.

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3 Results and Discussion

The Geological Survey of Brazil (SGB, 2024) monitors critical events in the national territory, with areas with high susceptibility to flooding and geological risk of landslides, as shown in Figure 6. The region to the right of the stream (Campo Verde neighborhood), comprised by Sections 1 and 2 of the study, has extensive flood risk ranges of up to 160 meters from the stream bed.

Figure 6 – Areas with high susceptibility to flooding (shown in blue) and geological risk (shown in yellow), according to SGB (2024)

Source: Brazilian Geological Survey (SGB, 2024).

Additionally, the presence of informal settlements in the vicinity of the stream was identified, highlighted in red in Figure 7, as well as the number of families in vulnerable conditions during flood events. Highlighting the need for technical urban drainage solutions aimed at increasing urban resilience in the region and preventing the occurrence of flooding.

Figure 7 – Occupations in risk areas along the Barbado Stream within the study area

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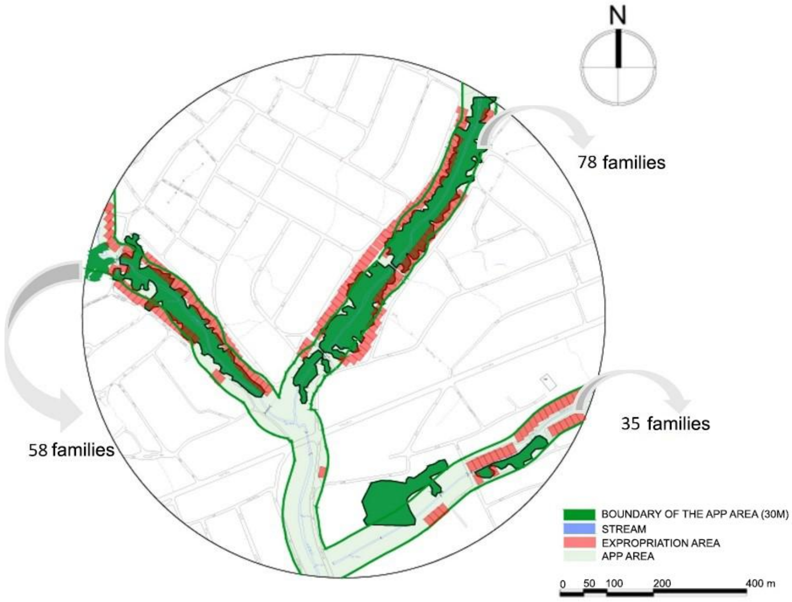
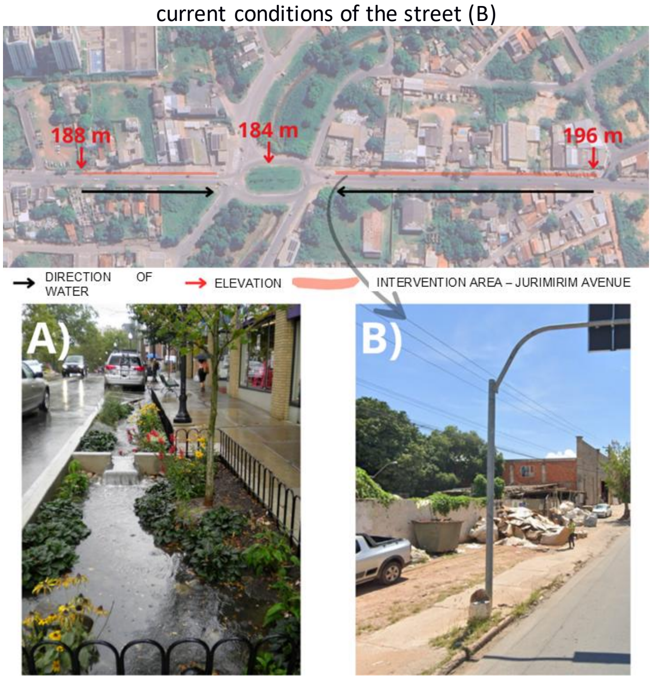


Source: Prepared by the authors (2025).

In light of this, the subsequent step consisted of conducting the feasibility study through the identification of areas suitable for the implementation of Green–Blue Infrastructure (GBI) solutions. Thus, along the main avenue (Avenida Jurumirim), a noticeable slope converging toward the Barbado Stream can be observed. Despite the presence of poor pedestrian infrastructure and limited tree cover, the avenue features sidewalks approximately 6 meters wide, which may facilitate the allocation of potential GBI interventions (Figure 8).

Figure 8 – Intervention area along Avenida Jurumirim, with an example of a rain garden (A) and an image of the current conditions of the street (B)



Source: Kurtz (2020); Google Earth (2024). Adapted by the authors.

According to Cuiabá's Minimum Geometric Standard (PGM), established in Article 180 of Municipal Complementary Law No. 389 (CUIABÁ, 2015), "the minimum width of sidewalks

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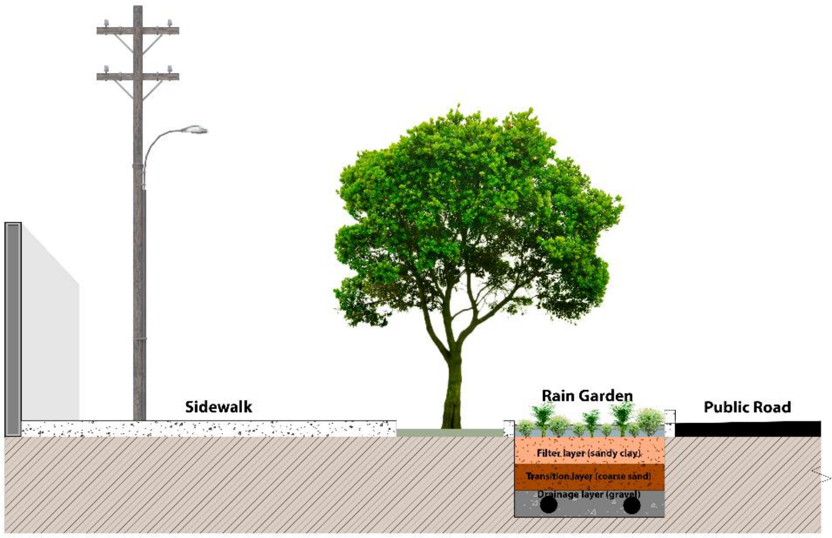
and adjacent pedestrian paths that comprise the road right-of-way shall be equal to one-sixth (1/6) of the PGM of the respective roadway." For the segment under study, this corresponds to a mandatory sidewalk width of 3.33 meters, of which 2.67 meters may be allocated to interventions.

Given this possibility, the feasibility of implementing Green–Blue Infrastructure (GBI) along Avenida Jurumirim was analyzed, considering the use of the 2.67 meters available on the existing sidewalk. The proposed solution consists of installing rain gardens along a 1.5-meter-wide strip, incorporating drainage layers to enhance stormwater retention capacity, as illustrated in Figure 9. Complementarily, to improve thermal comfort and pedestrian well-being, an additional 1.00-meter-wide strip was designated for urban tree planting, contributing to shading and surface temperature reduction.

Figure 9 – Intervention area along Avenida Jurumirim, with the addition of a rain garden and an urban tree-planting strip



Source: Prepared by the authors (2025).

In contrast, in Segment 2, Avenida Governador Dante Martins de Oliveira underwent renovation in 2021, resulting in the implementation of a grassed central median 8.5 meters wide, in addition to a bicycle lane and sidewalks. Despite this requalification, tree cover remains insufficient and, as noted by Rosa, Valin Jr., and Ribeiro Jr. (2017), soils in Cuiabá exhibit very low permeability coefficients, which significantly limits their capacity to store stormwater.

In light of this, it was decided to propose interventions exclusively within the permeable area of the central median through the implementation of a bioswale. This type of sustainable urban drainage infrastructure performs a dual function: infiltrating and filtering stormwater, thereby reducing the pollutant load reaching the stream. To this end, the use of a filtering layer composed of recycled construction and demolition aggregates is recommended as infiltration and water storage material to support preliminary treatment of runoff, given its storage capacity, approximately three times greater than that of natural aggregates, demonstrating its potential as a viable alternative for transition and drainage layers in bioretention swales (Qi; Xu; Wu, 2023).

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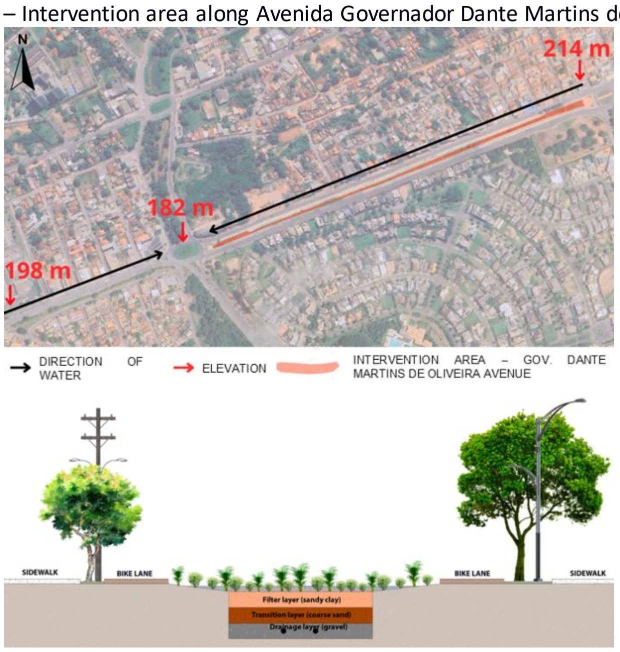
Accordingly, along Avenida Governador Dante Martins de Oliveira, the implementation of urban tree planting and a bioswale is proposed over a length of 850 meters, as highlighted in red in Figure 10.

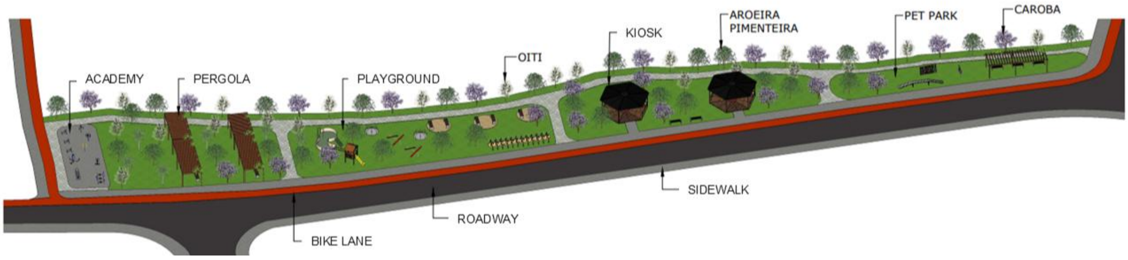
Figure 10 – Intervention area along Avenida Governador Dante Martins de Oliveira



Source: Prepared by the authors (2025).

The current condition of the Barbado Stream, as previously demonstrated, reveals its degradation and lack of integration with the city. These issues, combined with ineffective public management, often drive public opinion to support channelization, justified by expectations of real estate valorization. However, there are alternative ways to benefit the surrounding population and enhance the quality of these areas. One such alternative is the revitalization of water bodies through linear parks (blue infrastructure), incorporating elements such as bicycle paths, social gathering areas, playgrounds, outdoor fitness equipment, and walking trails, among others, as illustrated in the proposal shown in Figure 11.

Figure 11 – Linear park study for Segments 1 and 2 of the Barbado Stream



Source: Prepared by the authors (2025).

The incorporation of a bicycle path within the linear park along the stream would enable a connection with the existing cycleway on Avenida Governador Dante Martins de Oliveira, promoting active mobility and connectivity with other areas of the city. In addition, this urban requalification strategy contributes to protecting and restoring the ecosystem, increasing carbon sequestration, improving air quality, and supporting flood control. Alongside these

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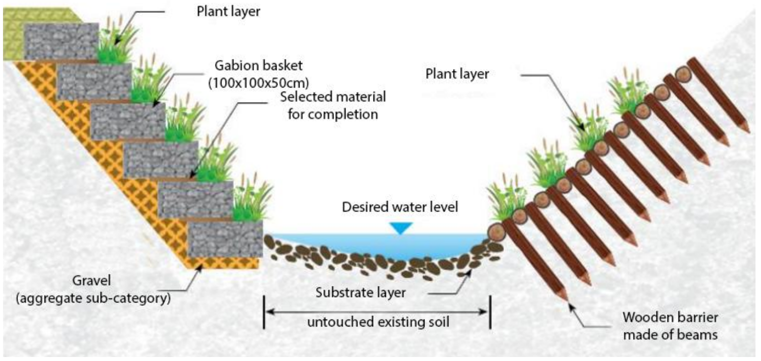
measures, the use of absorbent materials is essential, such as the application of porous permeable concrete on sidewalks.

Furthermore, given the current condition of the streambed, the use of bioengineering retaining structures is a solution aimed at controlling erosive processes. This ecological technique employs gabion baskets as retaining elements and/or timber beams, combined with low riparian vegetation on their surfaces to enhance water absorption. Such configurations help create a stepped profile, reducing the velocity of stormwater within the stream. Although gabions are traditionally filled with stones, recycled concrete waste may be used due to its similar density, posing no environmental risk because of its inert characteristics (NBR 10004, 2004), thereby enhancing the sustainability of this application. Consequently, this approach constitutes a Nature-Based Solution that integrates technical, ecological, economic, and aesthetic criteria, as illustrated in Figure 12.

Figure 12 – Nature-based solutions applied to retaining walls



Source: ABC Waters (SINGAPORE, 2011) - Our translation.

In conjunction with these technical measures, promoting public awareness and implementing effective public policies are essential for building a resilient city. An illustrative example is the initiative created by the municipal departments of Goiânia, Salvador, and Botucatu to encourage environmental preservation, known as *“Disque-Árvore”* (“Tree Hotline”). This program promotes the free distribution and planting of tree seedlings and, when necessary, carries out sidewalk concrete cutting to enable planting (Carvalho, 2024). In Goiânia, the project was launched in 2021 and has resulted in the planting of more than 9,000 trees along sidewalks. In Botucatu, the initiative began in 2018, and in that year alone, 4,899 seedlings were planted through the program.

Considering the range of challenges the world has been facing with respect to extreme climate events, urban resilience emerges as a fundamental prerequisite for a future that is both environmentally harmonious and socially safe. Therefore, integrating multiple green and blue infrastructure techniques represents a key strategy for mitigating and adapting cities to current and future challenges. In this context, the present investigation sought to elucidate the application of such techniques within the urban environment of Cuiabá, a city that has suffered for decades from drainage deficiencies and extreme heat conditions.

4 Conclusions

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Rapid urbanization in Cuiabá, combined with the degradation of water bodies, has intensified soil imperviousness and the covering of streams, with the Barbado Stream being the most affected. The consequences of these public actions (or the lack) thereof, have rendered areas adjacent to the stream susceptible to flooding and landslides, as documented in reports by the Geological Survey of Brazil (SGB) and the National Civil Defense.

Based on this investigation, a feasibility study grounded in green and blue infrastructure was conducted, aiming to adapt a segment of the city. The study prioritized the implementation of rain gardens and bioswales along avenues that convey the highest volumes of stormwater, with the objective of increasing soil permeability and stormwater storage capacity. In addition, investment in urban tree planting was identified as a determining factor in improving the local microclimate and reducing the effects of urban heat islands.

Finally, a proposal for a linear park along the stream was developed, aiming at the requalification of the degraded area through the application of bioengineering techniques to control erosion along the streambanks and provide greater stability. This intervention also seeks to enhance local biodiversity and contribute to the ecological resilience of the hydrological system.

In this way, the present study offers guidance for public-sector decision-makers, providing a promising pathway toward the development of resilient cities aligned with climate mitigation and adaptation strategies.

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ISSN 2318-8472, v. 14, n. 92, 2026

DECLARATIONS

AUTHOR CONTRIBUTIONS

- **Study Conception and Design:**
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- **Data Curation:** Fabio Friol Guedes de Paiva.
- **Formal Analysis:** Fabio Friol Guedes de Paiva, Diana Carolina Jesus de Paula, and Natallia Sanches e Souza.
- **Funding Acquisition:** This research received no specific external funding.
- **Investigation:** Fabio Friol Guedes de Paiva.
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DECLARATION OF CONFLICTS OF INTEREST

We, **Fabio Friol Guedes de Paiva, Diana Carolina Jesus de Paula, Natallia Sanches e Souza, and Erica Lemos Gulinelli**, declare that the manuscript entitled **"Green and Blue Infrastructure: Possibilities and Reflections on the Barbado Stream in Cuiabá, Mato Grosso, Brazil"** meets the following conditions:

1. **Financial Relationships:** We declare that we have no financial relationships that could have influenced the results or interpretation of this study. No funding institution or sponsoring organization was involved in the development of this research.
2. **Professional Relationships:** We declare that we have no professional relationships that could have affected the analysis, interpretation, or presentation of the results. No professional relationship relevant to the content of this manuscript has been established.
3. **Personal Conflicts of Interest**: We declare that we have no personal conflicts of interest related to the content of this manuscript. No personal conflict of interest related to the content of this study has been identified.