Soluções Baseadas na Natureza em Ação: Projetando um Parque Alagável para Promover a Sustentabilidade.

Nature-Based Solutions in Action: Designing a Floodable Park to Promote Sustainability

Soluciones basadas en la naturaleza en acción: Diseño de un parque inundable para promover la sostenibilidad

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Resumo: Este artigo apresenta uma proposta de requalificação urbana baseada em Soluções Baseadas na Natureza (SBN), com foco no projeto de um parque alagável no bairro Taboão, em Rio do Sul (SC), uma área frequentemente afetada por inundações e marcada por vulnerabilidade social. O objetivo foi desenvolver uma estratégia de intervenção que promovesse não apenas retenção hídrica, mas também inclusão social, restauração ecológica e melhoria da qualidade de vida

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local. A metodologia envolveu revisão bibliográfica, análise espacial com uso de Sistema de Informação Geográfica (SIG) e modelagem tridimensional em ambiente BIM (Archicad). O estudo também se beneficiou de contribuições conceituais e discussões desenvolvidas em colaboração com pesquisadores do IHE Delft Institute for Water Education, particularmente nas áreas de cidades-esponja e resiliência hídrica urbana. A escolha da área de intervenção considerou critérios como topografia, histórico de enchentes, ausência de infraestrutura verde e presença de uma comunidade em situação de risco. O projeto incorpora diversas soluções SBN, como jardins de chuva, biovaletas, cobertura vegetal e bacia de retenção permanente, respeitando as dinâmicas existentes e evitando o caráter de "vitrine" estética. Embora o estudo não conte com modelagem hidrológica detalhada, e encontre-se na fase conceitual, oferece subsídios para a discussão sobre requalificação urbana em territórios periféricos sujeitos a eventos extremos. A proposta enfatiza o uso social do espaço, a valorização das condições naturais e a transição para cidades mais resilientes e justas.

Palavras-chave: Soluções baseadas na Natureza; Infraestutura verde; Sustentabilidade; Parque alagável.

Abstract: This article presents an urban requalification proposal based on Nature-Based Solutions (NBS), focusing on the design of a floodable park in the Taboão neighborhood of Rio do Sul (Santa Catarina, Brazil), an area frequently affected by flooding and marked by social vulnerability. The objective was to develop an intervention strategy that not only supports water retention but also fosters social inclusion, ecological restoration, and improved quality of life. The methodology included a literature review, spatial analysis using Geographic Information Systems (GIS), and three-dimensional modeling in a Building Information Modeling (BIM) environment (Archicad). The study also benefited from conceptual contributions and discussions developed in collaboration with researchers from the IHE Delft Institute for Water Education, particularly in the fields of sponge cities and urban water resilience. Site selection was guided by criteria such as topography, flood history, lack of green infrastructure, and the presence of at-risk communities. The park design integrates multiple NBS features, including rain gardens, bioswales, a green roof pavilion, and a permanent retention pond, while respecting local dynamics and avoiding the creation of a detached, aestheticized "showcase." Although the study does not incorporate detailed hydrological modeling, and remains at the conceptual design stage, it contributes to the discourse on urban requalification in peripheral areas

Conflict declaration

Nothing to declare.

subject to extreme climate events. The proposal emphasizes the social use of space, the enhancement of natural conditions, and a broader transition toward more just and climate-resilient urban environments.
Keywords: Nature-Based Solutions; Green Infrastructure; Sustainability; Floodable Park.

Resumen: Este artículo presenta una propuesta de recalificación urbana basada en Soluciones Basadas en la Naturaleza (SBN), centrada en el diseño de un parque inundable en el barrio Taboão, en Rio do Sul (Santa Catarina, Brasil), un área frecuentemente afectada por inundaciones y marcada por vulnerabilidad social. El objetivo fue desarrollar una estrategia de intervención que no solo favorezca la retención de agua, sino que también promueva la inclusión social, la restauración ecológica y la mejora de la calidad de vida. La metodología incluyó revisión bibliográfica, análisis espacial mediante Sistemas de Información Geográfica (SIG) y modelado tridimensional en un entorno de Building Information Modeling (BIM) utilizando Archicad. El estudio también se benefició de contribuciones conceptuales y discusiones desarrolladas en colaboración con investigadores del IHE Delft Institute for Water Education, particularmente en las áreas de ciudades esponja y resiliencia hídrica urbana. La selección del sitio se orientó por criterios como topografía, historial de inundaciones, carencia de infraestructura verde y presencia de comunidades en situación de riesgo. El diseño del parque integra múltiples estrategias de SBN, incluyendo jardines de lluvia, bioswales, un pabellón con cubierta verde y una laguna permanente de retención, respetando las dinámicas locales y evitando la creación de una "vitrina" urbana desvinculada del contexto social existente. Aunque el estudio no incorpora modelaciones hidrológicas detalladas y permanece en una etapa conceptual, contribuye al debate sobre recalificación urbana en áreas periféricas sujetas a eventos climáticos extremos. La propuesta enfatiza el uso social del espacio, la valorización de las condiciones naturales y una transición más amplia hacia entornos urbanos más justos y resilientes frente al clima.
Palabras clave: Soluciones Basadas en la Naturaleza; Infraestructura Verde; Sostenibilidad; Parque Inundable.

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1 INTRODUCTION

Urban redevelopment plays a crucial role in improving quality of life and strengthening resilience, especially in areas that are socially and environmentally vulnerable. In the city of Rio do Sul, located in the Alto Vale do Itajaí region of southern Brazil, recurrent flooding has exposed structural weaknesses in the urban fabric, particularly in low-lying neighborhoods marked by precarious housing and limited access to public infrastructure.

While large-scale floods are common in the region due to climatic phenomena such as La Niña, this study focuses on localized flood events triggered by intense rainfall and aggravated by poor drainage systems, soil sealing, and disordered urban expansion. This research explores the potential of a floodable park as a local NBS to support urban adaptation and requalification in one of the most flood-prone and underserved areas of the city (Moosavi et al., 2021). Rather than seeking to solve regional hydrological issues, the project aims to transform a vulnerable urban site into a multifunctional public space that integrates ecological restoration, recreational use, and basic flood retention capacity.

The justification for the intervention lies in the urgent need to reclaim degraded spaces, reduce local flood exposure, and provide inclusive green infrastructure to communities with no access to parks or environmental amenities (Zoghi et al., 2025; Fang et al., 2023). The method involves a spatial analysis using Geographic Information Systems (GIS) to identify high-risk areas based on land use, topography, and flood exposure. The selected site, located in the Taboão neighborhood, was then modeled in 3D using Archicad, enabling the design of a park that incorporates a permanent pond, permeable surfaces, and native vegetation. Although this study does not include hydrological modeling, it contributes to the discussion on how spatial tools and landscape strategies can guide sustainable micro-scale urban interventions. The proposed design illustrates how floodable parks can act as adaptive green infrastructure, with both environmental and social benefits. In addition to its applied dimension, this study offers three main contributions to the current debate on Nature-Based Solutions in vulnerable urban contexts. First, it proposes an integrated methodological framework that combines GIS-based spatial diagnosis with BIM-based architectural modeling, strengthening the connection between territorial analysis and project development. Second, it advances the discussion on floodable parks at the micro-scale of medium-sized Brazilian cities, which remain underrepresented in international literature. Third, it critically addresses the risk of aestheticizing vulnerable territories by emphasizing functional, socially grounded design rather than iconic or showcase-oriented interventions. By articulating environmental, spatial, and social dimensions, the study contributes to a more context-sensitive and equitable understanding of urban resilience strategies.

2 RELATED WORKS

2.1 Nature-Based Solutions and Urban Requalification

NBS have emerged as strategic tools to promote more sustainable, resilient, and inclusive urban development (Moosavi et al., 2021). By incorporating natural elements and ecological processes into the planning and management of cities, NBS address not only environmental concerns but also social and spatial inequalities (Gómez-Baggethun & Barton, 2013; Cimatti et al., 2023). In areas marked by vulnerability, such as informal settlements, flood-prone zones, or neighborhoods with limited access to public infrastructure, NBS offer opportunities for ecological restoration, the creation of green public spaces, and the improvement of urban quality of life (Lam et al., 2025; Fang et al. 2023).

Among the various typologies of NBS, floodable parks stand out as multifunctional spaces that combine environmental benefits with recreational and educational functions. Although they may contribute to the regulation of surface runoff in localized flood events, their primary role in the context of this study lies in requalifying underused or degraded urban areas and increasing access to ecosystem services, especially in neighborhoods lacking green infrastructure (Le et al., 2018; Cimatti et al., 2023).

Floodable parks can include design elements such as permanent ponds, permeable surfaces, native vegetation, bioswales, or rain gardens. These features help reconnect urban populations with natural cycles, offering benefits such as microclimate regulation, biodiversity support, and improved landscape quality, even in the absence of hydraulic modeling or large-scale flood interventions (Markou, 2022; Tapia et al., 2025). In this sense, NBS are not limited to engineering solutions for flood control. They represent a paradigm shift toward integrated urban planning that values multifunctionality, community well-being, and environmental restoration. Especially in socially vulnerable areas, such interventions can reduce risk exposure, foster healthier environments, and create more inclusive and adaptive public spaces (Periçato et al., 2016; Schorn, Vieira 2023).

2.2 Green infrastructure as a tool for urban resilience and social inclusion

Green Infrastructure (GI) has emerged as a multifunctional approach that responds to the growing demand for urban development strategies capable of integrating natural systems into cityscapes (Ahern, 2007). Unlike traditional grey infrastructure, which often relies on rigid engineering solutions such as underground pipelines and concrete drainage, GI offers flexible, adaptive, and ecologically grounded interventions—including bioretention systems, green roofs, permeable pavements, and vegetated corridors—that enhance urban livability while contributing to environmental restoration (Meyer, et al. 2020; Adegun, 2017); .

From the perspective of stormwater management, GI can significantly reduce runoff volumes, delay peak flow, and increase the capacity for infiltration and water retention (Adegun, 2017; Khodadad et al., 2023). These hydrological benefits are often accompanied by broader co-benefits such as temperature regulation, improved air and noise quality, and enhanced biodiversity—factors that directly influence both physical and mental health in urban populations. In addition, GI plays a strategic role in reducing the urban heat island effect and strengthening adaptive capacity to climate change.

Despite its potential, implementing GI in informal or low-income urban areas presents challenges. Issues of land tenure, high urban density, and the risk of displacement in ecologically sensitive zones often hinder interventions in peripheral neighborhoods (Wang et al, 2024). However, GI also holds transformative potential in these same contexts, as many of these settlements are located in environmentally critical areas such as wetlands and floodplains (Adegun, 2017). When introduced through participatory and inclusive planning processes, green infrastructure not only supports ecosystem conservation but also helps fill service gaps in areas historically underserved by formal urban policies (Wang et al, 2024; Ahern, 2007).

In this light, green infrastructure contributes not only to environmental performance but also to social equity and urban resilience. Its multifunctionality makes it particularly suitable for integrated solutions in vulnerable contexts, where ecological interventions can simultaneously address stormwater management, access to public space, and environmental justice (Khodadad et al., 2023; Czechowski, 2015; Zhou et al., 2024).

2.3 Public space, vulnerability, and environmental justice in the urban periphery

Urban settlements located in low-lying areas near water bodies often face heightened risks associated with poor sanitation, environmental degradation, pollution, and limited access to safe public infrastructure (Canholi, 2005). In these contexts, the challenge of managing risk goes beyond natural hazards and includes the spatial and social vulnerability of marginalized communities (Schorn, Vieira 2023; Bulti et al., 2019). The implementation of green infrastructure has been increasingly recognized as a transformative strategy that not only enhances urban environmental quality but also promotes social inclusion and spatial justice (Khodadad et al., 2023; Baker et al. 2021). Unlike traditional grey infrastructure, green alternatives—such as urban parks and vegetated open spaces—offer multifunctional benefits, including improved stormwater management, biodiversity support, and accessible leisure areas in underserved neighborhoods (Zhou et al., 2024; Cimatti et al., 2023).

In this sense, the creation of floodable parks in vulnerable urban areas aligns with integrated sustainability frameworks that prioritize environmental, social, and economic dimensions (Librelotto et al., 2012). As Meyer et al. (2020) argues, flood-prone urban areas require a combination of structural and nonstructural measures that enable residents to coexist with water rather than eliminate it entirely. Among the structural strategies proposed, the establishment of public parks along riparian corridors is highlighted not only as an ecological solution but also as a social and spatial one—supporting environmental resilience while offering essential services to low-income populations. The park proposed in this study follows this principle by reclaiming a degraded area, aiming to transform it into a multifunctional public space that serves both ecological functions and the needs of a vulnerable community.

2.4 Flood Risk in Rio do Sul and Urban Vulnerability

The Itajaí River Basin, located in the state of Santa Catarina, Brazil, covers approximately 15,000 km² and has a long history of flood events. These floods are influenced by both natural features—such as steep topography and diverse soils—and anthropogenic factors, including urban expansion and land-use changes (Correa, 2022). Rio do Sul, situated at the confluence of the Itajaí do Sul and Itajaí do Oeste Rivers, lies in a particularly flood-prone area due to its location within the basin and the presence of multiple watercourses running through its urban core, as shown in Figure 1.

Figure 1: City of Rio do Sul hydrographic data

Source: author, 2025

Red arrows on the map (Figure 1) point to two of the city's most flood-prone neighborhoods: Canoas, located near the confluence of the rivers, and Taboão, positioned close to the distinctive 'S' curve. Due to their low elevation, both areas are typically among the first to be affected during flood events. Among flood disasters, one of the most severe occurred in September 2011, when the water level reached 13 meters and caused the displacement of over 15,000 people (Lapolli, 2013). More recently, in October and November 2023, Rio do Sul experienced the second-largest flood in recorded history (Figure 2). From October 13th to 19th, the Itajaí-Açu River remained above the 7.5 m flood alert level for a full 12 days, peaking at an extraordinary 11.86 m on October 13th Less than one month later, on November 18th, the river reached 13.04 m—only slightly below the catastrophic high of 1983—prompting the opening of 21 shelters, the displacement of almost 19,000 people, and the inundation of over half the city's streets. As such, the combination of rapid urbanization, impermeable surfaces, and occupation of floodplain areas has increased both the frequency and impact of these events.

Figure 2: Confluence of rivers, city's overall inundated

Source: ND Mais, 2023

Today, Rio do Sul faces not only hydrological challenges but also issues related to urban vulnerability and the lack of green infrastructure—especially in neighborhoods like Taboão, where low-income communities are disproportionately exposed to flood risks and have limited access to safe public spaces.

2.5 Similar parks

With the development of cities and the expansion of urban areas observed over the past century, there is an urgent need to develop strategies to mitigate the impacts of urbanization. According to Leite and Awad (2019), about 100 years ago, the urban population accounted for just 10% of the total. Today, more than 50% of the global population lives in cities, and by 2050 this number is expected to reach 75%. The main characteristics of uncontrolled urbanization include soil, river, and air pollution; soil sealing; and an increase in the impacts of natural disasters, including rising temperatures. According to the author, urbanization and increased income levels in these populations place greater pressure on energy and water resources, increase the need for waste disposal and treatment (both solid and liquid), and contribute to greater air pollution (Leite, Awad, 2019).

NBS thus emerge as strategies that can be used to reduce the impacts of urbanization and climate change, while also contributing to improvements in the quality of life for urban populations (Hannes, 2017). As cities become greener and more permeable, air and water quality can improve, and problems related to temperature and excess rainfall may diminish.

The following section presents three case studies as part of the theoretical framework that supports the study of floodable parks and their characteristics. While these large-scale international examples demonstrate the infrastructural potential of floodable parks, the present proposal differs by operating at a neighborhood scale within a medium-sized Brazilian city, emphasizing social proximity and low-cost adaptability rather than monumental landscape transformation.

2.5.1 Beijing Olympic Forest Park

The Beijing Olympic Forest Park is one of the largest examples of a floodable park in China, designed by Hu Jie for the 2008 Olympic Games. Covering an area of approximately 11.5 km², the park was created with the goal of improving the environmental quality of Beijing—a city known for its high levels of pollution. The park's infrastructure includes an extensive network of lakes, wetlands, and marshes that play a crucial role in stormwater retention and filtration, helping to reduce flooding and replenish groundwater reserves.

Additionally, the park is home to a diverse range of native flora and fauna, including plant species such as cattails, reeds, irises, and cannas, which assist in water purification and provide microhabitats for wildlife. Regarded as the city's "green lung," the park not only delivers essential ecosystem services but also offers recreational and educational spaces for the population. It exemplifies how NBS can be integrated into urban planning to balance development and sustainability.

2.5.2 Yanweizhou Wetland Park

Another example of a floodable park in China is the Yanweizhou Wetland Park, located in the city of Jinhua, at the confluence of the Yiwu and Wuyi Rivers. The park was designed with the dual purpose of restoring areas degraded by former sand mining activities and strengthening the city's water resilience through stormwater retention. The project included elements such as elevated walkways that connect different parts of the city without interfering with the natural flow of water, as well as a series of flood zones that function as reservoirs during both drought periods and extreme rainfall events.

As a result of implementing these strategies, Jinhua was recognized as a "sponge city," a concept promoted by the International Organization for Sustainable Cities (IOSC) and the United Nations Environment Programme (UNEP). The term refers to cities designed to efficiently absorb, store, and reuse rainwater, reducing flood risk and promoting sustainable water resource management. The park incorporates various NBS strategies, such as pathways made from permeable materials and the restoration of riverbanks, reinforcing the importance of adapting urban environments to the natural hydrological cycle.

2.5.3 Parque Orla Piratininga

In Brazil, one of the most prominent examples of NBS is the Parque Orla Piratininga, located in the city of Niterói, Brazil. Situated in a permanent preservation area, the park is part of the "Niterói Mais Verde" program and follows the principles of ecological landscaping. According to Vellozo (2022), its design is based on concepts such as urban resilience, ecosystem services, and sustainable drainage.

With a total area of 680,000 m², the park features 35,290 m² of filtration gardens—an innovative solution for water purification and the maintenance of soil permeability. These gardens use aquatic and marginal plants to remove pollutants from lakes, rivers, and watersheds, functioning as a natural barrier against water contamination. Moreover, the park promotes environmental education and awareness about the sustainable use of water resources, serving as a model for replicating green infrastructure in other Brazilian cities. Its implementation demonstrates the potential of NBS to mitigate urban problems and restore degraded ecosystems, while also creating high-quality public spaces for the population.

2.5.4 Comparative

The comparative analysis of the three parks—Beijing Olympic Forest Park, Yanweizhou Wetland Park, and Parque Orla Piratininga—makes it possible to identify evidence of the positive impacts of NBS in different urban contexts. As presented in the comparison matrix, the Beijing Olympic Forest Park stands out for its large area (11.5 km²) and the harmonious integration of lakes and wetlands, which provide high water retention capacity and support the preservation of local biodiversity. This park exemplifies how green infrastructure can reduce urban heat islands and improve citizens' quality of life, reinforcing the ideas of Hannes (2017). In the case of the Yanweizhou Wetland Park, its strategic location at the confluence of the Yiwu and Wuyi Rivers demonstrates an innovative approach to managing large volumes of rainwater while also promoting the rehabilitation of degraded areas. This experience supports the findings of Kabisch et al. (2022) regarding the effectiveness of NBS in high flood-risk areas, contributing to urban connectivity and the integration of natural spaces with infrastructure.

Finally, the Parque Orla Piratininga, located in Niterói, illustrates an application adapted to the Brazilian reality, where filtration gardens play a crucial role in reducing water pollution and maintaining soil permeability. This solution, based on the principles of ecological landscaping, reflects the guidelines proposed by Cockram (2017) and Kabisch et al. (2022), demonstrating that even in highly urbanized settings, it is possible to reconcile urban development with environmental preservation.

The discussion highlights the need to adapt these solutions to the Brazilian context—characterized by tropical, subtropical, and humid tropical climates—and to promote research that integrates international knowledge with local conditions. Such integration can offer guidance for public policies and urban planning practices that prioritize not only the mitigation of environmental impacts but also the improvement of quality of life and the sustainability of cities.

3 METHODOLOGY

3.1 Initial phase

The methodology adopted in this study involved multiple stages. The first phase consisted of a literature review focused on the multifunctionality of NBS in urban settings, especially in vulnerable communities with limited green infrastructure. Key concepts explored include environmental justice, green infrastructure planning, and floodable parks as adaptive public spaces. Special attention was given to the history of flooding events in the city of Rio do Sul and their associated social, environmental, and economic impacts. Subsequently, three exemplary floodable parks—two international and one national—were selected for reference based on their relevance to the themes of flood resilience, ecological restoration, and community benefit. Although these were not explored in the form of detailed case studies, key characteristics and design strategies of three notable examples were discussed. Their key design features, spatial strategies, and multifunctional roles were summarized to support the conceptual development of the local proposal.

3.2 Spatial Analysis and selection area

Following the initial phases, the study advanced to a spatial data analysis component. In order to determine the most suitable area for implementing the floodable park, a Geographic Information System (GIS) was employed as a decision-making tool, as suggested by Cursino et al. (2021). Spatial analysis was conducted to identify zones of vulnerability based on flood risk, topography, and patterns of land use. This process involved overlaying multiple geospatial data layers, including flood maps at various water levels and urban occupation maps of the municipality of Rio do Sul, according to data from Wormsbecher (2017) and (Comitê do Itajaí, 2010). These insights enabled a more precise understanding of opportunities for ecological restoration, social benefit and the potential for targeted interventions. The outputs from the spatial analysis—including flood risk zones, topographical gradients, and land occupation patterns from Taboão neighborhood—are presented in the results section to support the justification for selecting the intervention area.

3.3 Guidelines for Designing a Multifunctional Park

The design of the proposed floodable park was guided by principles of multifunctionality, resilience, and inclusiveness, grounded in both spatial analysis and literature on NBS. The key criteria considered included: (i) the need to restore ecological functions along the Taboão stream; (ii) the opportunity to repurpose a flood-prone and previously inhabited area for safe public use; and (iii) the lack of green public spaces in the neighborhood, which informed the inclusion of recreational and educational features. As part of the data collection process, a field visit was conducted to better understand the physical and social dynamics of the Taboão neighborhood. During this visit, the team was welcomed by a local community leader, who generously shared her experiences with past flood events, as well as information regarding relevant aspects of neighborhood life. Although the conversation was informal and did not follow a structured data collection protocol, it played a significant role in shaping the project approach. The insights gathered reinforced the importance of minimizing disruptions to existing social dynamics and respecting the lived experiences of residents. This exchange helped guide the proposal toward a strategy of low-impact intervention and spatial restoration, grounded in local knowledge and context sensitivity.

3.4 Modeling

This study does not include detailed hydrological or hydrodynamic modeling, acknowledging the technical and operational limitations of such analysis within its current scope. Instead, it focuses on the local scale of the Taboão neighborhood. While the lack of modeling limits hydraulic precision, it does not compromise the study’s main objective, which is to propose a resilient urban requalification strategy. Future stages of the project may incorporate technical modeling to assess the park’s performance under extreme weather scenarios. The intervention proposal was developed using Archicad (BIM software), which allowed for the integration of spatial data from GIS analysis into a 3D design environment. The integration of GIS-based spatial diagnosis with BIM-based design modeling represents an important methodological contribution, bridging analytical territorial mapping with project-level architectural development.

The use of BIM tools allowed not only the geometric representation of the proposal but also enhanced the decision-making process by enabling the simulation of interactions between built and natural elements, such as real terrain conditions. The 3D environment facilitated the adjustment of design elements to real-world constraints, such as slope, elevation, and flood exposure. To enhance visual communication and support community engagement, the 3D model of the park was first rendered using Archicad's native visualization tools. Subsequently, the images were processed through Sora, an AI-based rendering platform, to achieve greater photorealism. This step aimed to improve the visual quality of the proposal and provide more accessible, realistic representations of the future intervention. Furthermore, the visual outputs generated contributed to the communication of the project’s goals and spatial qualities, serving as an important tool for community engagement and future stakeholder presentations.

4. RESULTS AND DISCUSSION

4.1 Intervention area: Justification

The maps and spatial outputs generated through GIS analysis, as illustrated in Figures 3 and 4, provide visual evidence supporting the selection of Taboão as the intervention site, which shows the overlap of flood zones at different river stages across the urban areas of Rio do Sul.

Figure 3: River level at the 8-meter mark

Figure 4: River level at the 9-meter mark

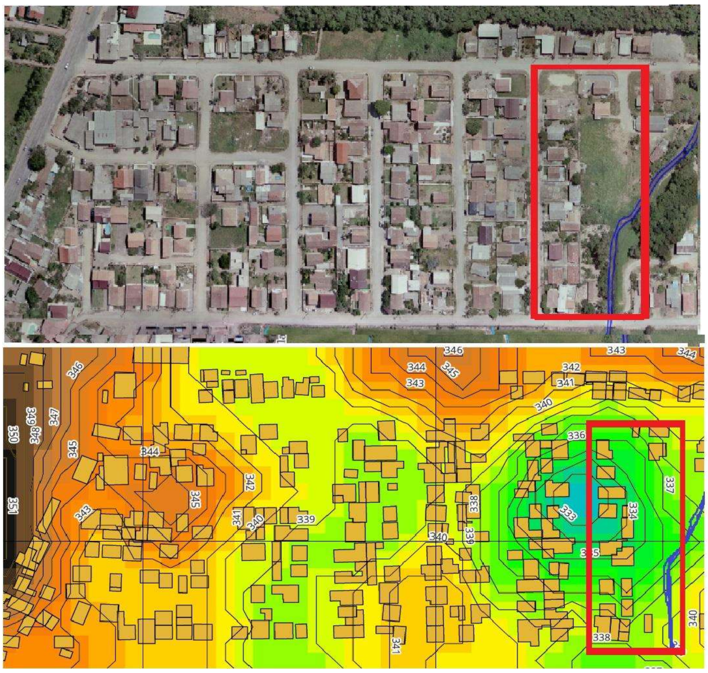
Source: author (2025)

Data from past flood events (1983, 2011, 2023) in the city indicate that certain areas begin to flood when the river reaches the 7-meters flood stage. As mentioned before, the red arrows on the map highlight two key neighborhoods in the city: Canoas (to the left, near the river confluence) and Taboão (to the right, adjacent to the 'S'-shaped curve). Both are situated in low-lying areas and are among the first to be impacted during flood events.

Taboão was selected due to a combination of factors: lower elevation, presence of preserved natural elements, absence of public green spaces, and concentration of low-income households. Canoas, although also flood-prone, already hosts the city's main park and presents less potential for spatial transformation. In addition to spatial vulnerability and the absence of green infrastructure, the selection of the Taboão neighborhood was also influenced by its physical and hydrological characteristics. The area is traversed by a small watercourse—Ribeirão Taboão—and contains elements that reinforce its ecological and landscape potential for the implementation of a floodable park. The neighborhood also retains a natural character, with low-density housing and proximity to vegetated areas, which facilitated integration with nature-based strategies.

To support the identification of the most suitable location for the floodable park within the Taboão neighborhood, a topographic map was generated in GIS, as illustrated in Figure 5. This map uses a color gradient—ranging from green (lower elevations) to orange (higher elevations)—to represent slope variation, with contour lines labeled by elevation. Orange polygons indicate existing residential structures. A satellite image from Google Maps was also used as a reference base, with the Taboão stream highlighted in blue for hydrological orientation. Both maps feature a red rectangle outlining a specific area identified as critical due to its low elevation, approximately 333–334 meters, and its proximity to the stream.

Figure 5: Taboão's satellite image from Google Maps (above) | Gradient topographic map from GIS (below).



Source: author (2025)

In this area, houses are frequently affected by localized flash floods, even when the river is below its major flood thresholds. Although no population was actually displaced in this study, the design concept explores the hypothetical relocation of approximately 15 residences to a safer, higher portion of the same neighborhood. This assumption is presented strictly at a conceptual level and would necessarily depend on future socio-economic assessments, participatory planning processes, and public policy frameworks to ensure ethical and equitable implementation. The vacated area, due to its flood exposure and ecological potential, is reimagined in the proposal as a floodable park. This approach transforms a high-risk zone into a multifunctional public space that improves environmental quality and promotes local resilience.

It is important to distinguish between hazard and risk in the context of flood-related urban planning. In this study, flooding itself is understood as the hazard—a recurrent natural phenomenon in Rio do Sul. However, the risk arises from the presence of exposed and vulnerable populations living in areas subject to frequent inundation, such as the low-lying sections of the Taboão neighborhood.

The intervention proposed here does not aim to eliminate the hazard, but rather to reduce risk by transforming a high-exposure area into a multifunctional public space that absorbs excess water and removes residential occupation from dangerous zones. This approach aligns with the broader understanding of risk as a product of hazard and vulnerability, as highlighted by Schorn and Vieira, (2023) and Bulti et al. (2019).

4.2 Modeling & NBS

The design of the floodable park incorporates a variety of NBS, each selected for its specific environmental and social functions. Table 1 summarizes the key strategies applied—such as the use of a permanent retention pond, rain gardens, permeable surfaces, and native vegetation—and their corresponding roles in promoting water retention, biodiversity, and community well-being. These elements were not randomly chosen; rather, they were directly inspired by the existing ecological patterns within the site.

To ensure continuity between spatial diagnosis and design development, the elevation data and contour lines produced in GIS were imported into Archicad, where a digital terrain model (DTM) was generated.

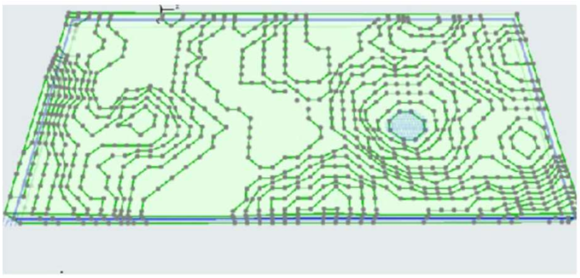
Table 1 - NBS presented in the project

Solution	Function
Retention Basin	Reduce the likelihood of flooding. When integrated into parks, they create opportunities for recreation, environmental education, and landscape enhancement.
Green Roofs	Store rainwater. Reduce pollution in water sources by slowing surface runoff, on a smaller scale compared to other solutions.
Wetlands (Riparian Zones)	Filter water, retain pollutants, recharge aquifers, and promote biodiversity.
Urban Tree Planting	Enhances rainwater infiltration into the soil. Improves urban space and can serve as a tool for environmental education through participatory planting programs.
Rain Gardens	Reduce the need for water treatment and irrigation by allowing rainwater to infiltrate into the soil, supporting groundwater recharge.
Bioretention Cells (Biovault)	Facilitate rainwater conveyance and infiltration, reducing the load on drainage systems.
River	Maintaining riparian vegetation and restoring degraded areas along riverbanks significantly reduces water pollution and creates opportunities for recreation, tourism, and education.

Source: authors (2025).

The 3D model, as illustrated in Figure 6, accurately represents the site's topography, including its natural slope patterns and elevation variations. In the initial modeling phase, structural elements such as buildings had not yet been added; the focus was on understanding the landform to inform spatial decisions. The lowest area on the terrain, previously identified in the GIS analysis as prone to flooding, was designated as the site for the retention basin.

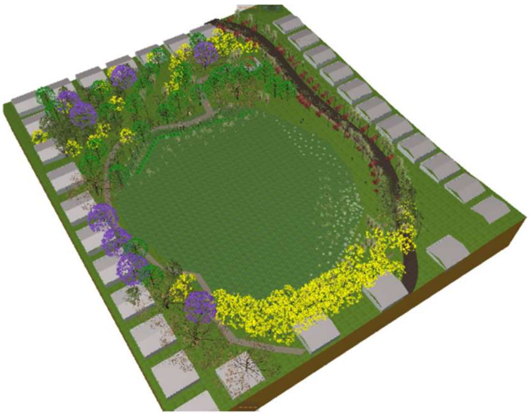
Figure 6: Digital terrain model of the area



Source: author (2025)

In the subsequent design phase, the floodable park was fully modeled within Archicad, as illustrated in Figure 7. Key elements were inserted, including the pond, permeable zones, vegetated areas, and circulation paths, all adjusted to the terrain's real conditions. This step marked the translation of geospatial data into a structured urban proposal.

Figure 7: Design phase in Archicad



Source: author (2025)

The area contains preserved fragments of the location's natural condition, showcasing dense greenery and native plant assemblages. The park design seeks to replicate and restore this type of environment, integrating native species and ecological structures as guiding references for landscape composition. In this way, the proposed intervention not only addresses urban vulnerability and flood exposure but also reinforces local ecological identity, aligning with broader goals of environmental restoration and urban resilience.

4.3 The intervention: Taboão PARK

The overall plan of Taboão PARK was designed as a multifunctional space that integrates NBS to address urban sustainability challenges, central to its design is the reforestation of native vegetation and the restoration of water-absorbing plants around the pond, enhancing the park's ability to retain stormwater. To communicate the project's vision more effectively, particularly in outreach and dialogue with local stakeholders and the community, Figures from 8 to 14 aim to support understanding and engagement, reinforcing the multifunctional nature of the proposed intervention, with letters 'a' to 'f' labeling the areas.

The permanent pond visible in the general plan in Figure 8 acts as a water retention basin and wetland (riparian zone), storing excess runoff during heavy rains and contributing to local biodiversity. When not inundated, the park fosters social interaction and well-being, aligning ecological restoration with urban quality of life.

Figure 8: retention basin, general plan

Source: author (2025)

By combining green infrastructure with resilient urban planning, the park exemplifies a sustainable approach to addressing climate-related risks while enhancing the livability of urban spaces. The reforestation of the vegetation (Figure 9) is characterized by a dense canopy of native trees, providing shade and enhancing the park's microclimate.

Figure 9: a- reforestation (urban tree planting)

Source: author (2025)

Overall, it is possible to note that the urbanized area at a higher elevation (Figure 9), indicates the park's strategic placement within the local topography. This positioning highlights the role of the park as a buffer zone, mitigating flood risks while providing an ecological corridor between the built environment and natural systems (Figure 10).

Figure 10: b- riparian zone (wetlands), ecological corridor

Source: author (2025)

The pathway itself (Figures 11) ensures safe pedestrian and bicycle circulation even during wet periods, reinforcing the park's multifunctionality and resilience.

Figure 11: c- pathway connecting people

Source: author (2025)

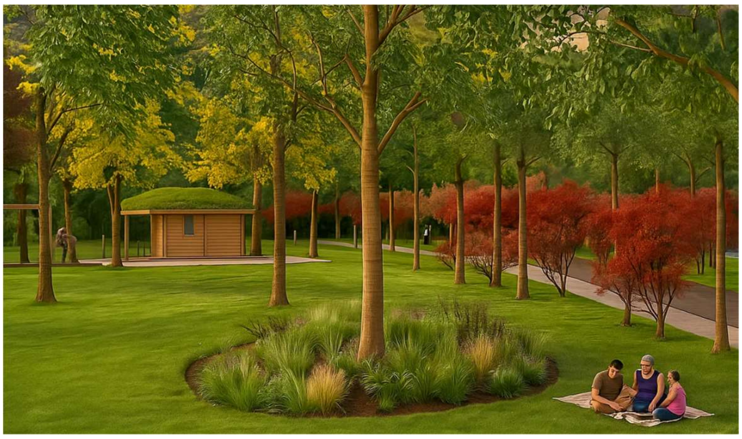
Beyond its local flood mitigation function, the park serves as a vibrant public space with amenities like benches and a children's play area, picnic area, promoting community engagement and leisure (Figures 12).

Figure 12: d-pond in a dry season, leisure

Source: author (2025)

Surrounding the building and scattered throughout the park are rain gardens (Figure 13) positioned strategically around the base of trees. These planting beds are designed to capture and filter stormwater runoff, facilitating groundwater recharge while supporting native vegetation. A small wooden building with a green roof functions as a central, gathering point, facility housing the restrooms.

Figure 13: e- rain gardens, green roofs



Source: author (2025)

The vegetated roof not only blends harmoniously into the landscape but also improves insulation, promotes biodiversity, and retains rainwater—reducing runoff during heavy rainfall. Along the elevated wooden walkway, bioretention swales (bioswales) are visible (Figure 14), gently sloped and densely planted with grasses and shrubs. These features guide excess water during precipitation events and contribute to the park's stormwater management capacity without compromising accessibility.

Figure 14: f- bioretention swales, children's play area

Source: author (2025)

Together, these NBS elements create a cohesive landscape that balances ecological function, flood mitigation, and community use, offering an immersive and sustainable experience for residents.

4.4 Discussion

Despite the contributions of this proposal, certain limitations must be acknowledged. The study does not include detailed hydrological or geotechnical modeling, which would be necessary for a full technical validation of the proposed interventions. Additionally, while the selected site is currently designated as a residential zone in the city's official land use plan, the frequent flooding and low elevation of the area raise concerns about the long-term suitability of permanent housing in this location. Although this research does not seek to question current regulations, the findings suggest the potential benefit of reclassifying such flood-prone zones as environmental buffer areas or green infrastructure corridors. This would not only align with sustainable urban planning principles but also help prevent future socio-environmental vulnerability. Further studies involving local authorities, community input, and technical assessments could support such a re-evaluation.

Although the proposal incorporates ecological design strategies and visual quality, the park is not intended as a symbolic "showcase" of environmental innovation detached from its context. Rather, it is conceived as a functional public space, designed with and for the community that inhabits the surrounding area. The goal is not to produce an aestheticized landscape to be admired from a distance, but to create an accessible, safe, and meaningful place for leisure, gathering, and daily use by residents. In this sense, the design privileges simplicity, functionality, and local identity, seeking to avoid the alienation often caused by overly stylized interventions in vulnerable neighborhoods. The park aims to reflect the reality and aspirations of its users, serving as an instrument of urban equity, not as an imposition of external aesthetic or ecological ideals.

The implementation of NBS in urban settings reveals not only their technical effectiveness but also their broader potential for environmental and social transformation. While this proposal is still at the conceptual stage, it aligns with established evidence showing that NBS can address multiple urban challenges simultaneously—particularly in vulnerable territories. One of the most evident contributions is the role of vegetation in regulating urban microclimates. The incorporation of tree canopies, green roofs, and permeable landscapes reinforces the documented cooling potential of vegetated urban systems, as widely discussed in studies on urban heat mitigation and ecosystem services (Zhou et al., 2024; Wang et al., 2024). Although the present proposal does not quantify thermal performance, its spatial configuration aligns with established evidence indicating that even small-scale green interventions can significantly improve local microclimatic conditions in vulnerable neighborhoods.This local intervention, though limited in scale, suggests how even small ecological insertions can mitigate temperature extremes and improve everyday conditions for residents.

In the context of stormwater management, NBS such as retention ponds, bioswales, and rain gardens are designed to work with natural hydrological processes rather than override them. In doing so, they reduce surface runoff, ease the pressure on drainage systems, and promote gradual water infiltration—actions particularly valuable in cities where impermeable surfaces dominate and flood events are recurrent. While the absence of hydrodynamic modeling limits the technical validation of runoff reduction performance, the spatial logic of the proposal reflects principles consistent with contemporary low-impact development strategies and nature-based stormwater management frameworks (Markou, 2022). In this regard, the project contributes conceptually to discussions on how spatial planning tools can operationalize ecological processes within urban design. Furthermore, the integration of GIS-based spatial diagnosis and BIM-based design modeling demonstrated in this study suggests a replicable workflow for small and medium-sized municipalities that may lack access to complex hydraulic simulation tools. By combining territorial-scale vulnerability mapping with project-level spatial development, this approach enables context-sensitive interventions grounded in available technical resources.

Beyond environmental regulation, NBS contribute to the requalification of degraded urban areas through the creation of multifunctional public spaces. These spaces serve not only ecological purposes but also social ones, offering areas for leisure, education, and collective use, especially in neighborhoods historically excluded from formal planning processes. The potential for biodiversity restoration, too, should not be overlooked: even modest interventions can serve as ecological connectors and refuges for native species, reinforcing urban resilience.

These findings reinforce broader discussions in the literature regarding the integrative nature of NBS, which engage environmental, social, and economic dimensions of sustainability. The potential risk of aestheticizing vulnerable territories through ecological design interventions deserves critical consideration. As highlighted in debates on environmental justice and urban green transitions, sustainability-oriented projects may inadvertently reinforce spatial inequalities if not grounded in participatory and socially responsive frameworks. The present proposal seeks to mitigate this tension by prioritizing functionality, accessibility, and contextual integration over iconic or image-driven design solutions (Gómez-Baggethun & Barton, 2013; Cimatti et al., 2023).

CONCLUSION

This study developed a conceptual proposal for a floodable park based on Nature-Based Solutions (NBS), aimed at addressing urban vulnerability and promote environmental and social resilience in the Taboão neighborhood, in the city of Rio do Sul, Brazil. Through a combination of literature review, spatial analysis using GIS, and 3D modeling with BIM tools, the project identified and transformed a high-risk, flood-prone area into a multifunctional public space that prioritizes both ecological restoration and community well-being.

The selection of the site was guided by criteria such as flood exposure, topography, social vulnerability, and the absence of public green infrastructure. The proposed design incorporates multiple NBS strategies, including a permanent retention pond, bioswales, rain gardens, and a green-roof pavilion, aiming to restore natural hydrological functions while offering recreational and educational value to the local population. Visual representations were employed to enhance communication and support stakeholder engagement, reinforcing the park's intended role as an accessible, everyday public space rather than a symbolic "green showcase.

While the project does not include detailed hydrodynamic modeling, it contributes to the discourse on how small-scale, context-sensitive interventions can effectively mitigate risk and improve urban quality of life in vulnerable areas. It also raises broader questions about land use planning in flood-prone zones and the potential need to reclassify such areas to prioritize ecological and social functions over residential expansion.

By integrating environmental, social, and spatial dimensions, this work reinforces the value of NBS as tools for equitable urban transformation. Beyond its local application, the study advances a replicable methodological pathway for integrating spatial diagnosis and architectural modeling in the implementation of nature-based solutions. Operating at the neighborhood scale within a medium-sized Brazilian city, it broadens the empirical base of NBS research beyond the large metropolitan contexts typically represented in international literature. Rather than framing floodable parks solely as hydraulic devices, the study positions them as instruments of spatial justice, highlighting the importance of interdisciplinary and context-sensitive approaches in climate adaptation planning. Future research may expand this approach by incorporating hydrological simulations, participatory planning processes, and long-term monitoring strategies.

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