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THE INSERTION OF GREEN <BLUE> INFRASTRUCTURE IN URBAN AND REGIONAL PLANNING: BARRIERS AND INVISIBILITY

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ABSTRACT

The concept of Green Infrastructure (GI) generally refers to issues related to sustainability, green spaces and is associated with Sponge Cities (SCP), Nature-based Solutions (NbS), and water management, such as Best Management Practices (BMPs) and Low Impact Development (LID). Included in this concept is Blue Infrastructure (BI), which is implied in many studies and even implicit in others. This research investigates the integration of Blue Infrastructure (BI) in the link between Green Infrastructure (GI) and urban and regional planning. Through an analysis of 50 scientific articles, the visibility of BI in strategies for sustainable urban and regional planning using GI was observed. The publications show varied levels of exposure and emphasis on BI, which is often implicitly integrated within the broader concept of GI. The goal of this paper is to demonstrate that the role of BI extends beyond water resource management, flood control, and mitigation solutions, and that, in order to increase urban sustainability and resilience, its interconnection with other planning elements must be considered from the start of projects and interventions. As part of an urban management system that contributes to several ecosystem services, this paper emphasizes the critical importance of increased visibility and integration of BI in the urban and regional planning process so that, in the face of current climate challenges, sustainable and resilient landscapes can be regenerated and/or built.

Keywords: Blue Green Infrastructure. Urban and Regional Planning. Sustainable Development. Green Infrastructure. Water Management.

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INTRODUCTION

The escalation of climate disasters, combined with rising urbanization and increased stresses on natural systems, has underlined the need to reconsider Urban and Regional Planning (URP) procedures to achieve resilience and sustainability. In this setting, green infrastructure (GI) emerges as a multifaceted concept that includes actions that connect ecosystems, mitigate climate effects, and promote urban sustainability (AHERN, 2013; MELL, 2010, 2015; PAULEIT et al., 2017). According to studies, despite its importance and acknowledgment for its contribution to urban resilience, GI adoption continues to confront considerable financial, institutional, social, and technological challenges (ELDERBROCK et al., 2020; MATSLER et al., 2021; REU JUNQUEIRA et al., 2023; WILFONG et al., 2023). Between the academic and practical fields, there are also the difficulties of translating GI, of its knowledge dissemination. (SINNETT et al., 2018)

Benedict and McMahon's (2006) pioneering GI concept, “an interconnected network of protected land and water that supports native species, maintains natural ecological processes, sustains air and water resources and contributes to the health and quality of life for communities and people” (in PELLEGRINO and AHERN, 2023), includes the blue infrastructure and the importance of its ecosystem services in supporting these processes. The connectivity present in this concept, a principle dear to ecological landscape planning, reinforces the interdependence between natural and human systems (FLETCHER et al., 2014; MELL, 2010; NDUBISI, 2002) and emphasizes the importance of having a consensus on the concept and its terms, so that there is fluidity between planners, communities, policy makers, stakeholders and others involved in both the planning and implementation of GI (FLETCHER et al., 2014; MATSLER et al., 2021; MELL, 2010).

The divergence in nomenclature, definitions and objectives of GI, depending on the area or geographic location, can hinder its application, planning, maintenance and its benefits (MASTLER et al., 2021; MELL, 2010). As noted in this study, the term "GI" is frequently used widely and generically, embracing its multipotentiality while ignoring or handling blue infrastructure (BI) separately. The opposite occurs in France, where the term Trame verte et Bleue (TVB) refers to a concept and guidelines drawn from the Grenelle I Law of 2009 (CENTRE DE RESSOURCES TRAME VERTE ET BLEUE, n.d.). It increases the visibility of BI and assures equality with GI in urban and regional planning procedures.

The term Blue-Green Infrastructure (BGI) has recently been used to refer to TVB as well[4] This leads to the question: how is BI considered in studies addressing the process of urban and regional landscape creation or regeneration?

The purpose of this study is to better understand how water resources are seen when GI is incorporated into urban planning, as well as to highlight the obstacles and opportunities for using BI in spatial planning or regeneration. The analytical approach included a literature review of works published between 2018 and 2024 that addressed the intersection of "water management" and "water resources" in urban and regional planning. This provided a wide view of how BI, which is incorporated into the notion of GI, has been regarded in academic discourse, with a significant impact in the practical sector. This methodological decision is justified by the necessity to map the existing state of knowledge, uncover trends, and highlight crucial spots for future study and policy development. The emphasis on literature review, rather than a traditional systematic review, enabled the examination of the work of writers whose works were most closely related to the issue (intersection of BI and urban and regional planning), as determined by the database's filters.

The findings show that, despite an increase in the frequency and intensity of climatic disasters, as well as a rising amount of literature on the subject, BI, which is incorporated into the concept of GI, is often overlooked in urban planning contexts. BI appears in studies on water management systems or is a major issue in flood research and prevention. Such neglect jeopardizes cities' ability to adapt to climate change and limits the usefulness of GI as a tool for social and environmental justice (PAULEIT et al., 2017). Much of the "Water management" literature focuses on the design of infrastructures and/or systems related to water resources, with minimal consideration given to organicity and the imperative of considering the system as a whole. The continuum in urban and regional planning should be examined not only in terms of grid connectivity, but also in terms of agent involvement and project outcomes. By linking Anne Spirn's continuum (SPIRN, 1995) to the connectedness explored by Ndubisi (2002) and Benedict and McMahon (2006).

The relevance of this study stems from its contribution to presenting the status of BI in scientific articles dealing with the relationship between GI and URP, thereby filling a gap and providing a critical and integrated view of the role of BI in urban planning. In doing so, it

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[4] The recently diffused concept of BGI was initially based on Benedict and McMahon (2006), which was later broadened globally and consolidated as Green Infrastructure (GI) (MELL and SCOTT, 2023).

hopes to not only inform but also influence scholarly and practical debates, encouraging more inclusive and effective policies that recognize BI as an essential component of urban resilience.

METHODOLOGY

To support and comply with the purpose of the research, a literature analysis was conducted, allowing for a more comprehensive view of the topic as well as critical and synthesis integration of pertinent study findings. Data was collected using the Web of Science database (WOS) and Scopus. In both databases, the search began with the umbrella term "Green Infrastructure"; Topic (5,889 entries) and Article title, Abstract, Keywords (7,564 items) encompassing production from 1995 to 2024. The time span of 2018-2024 was added, with only peer-reviewed papers and early accesses excluded, yielding 4,712 articles in WOS and 4,353 in Scopus.

The filters applied in the WOS study yielded 725 papers, with just the following categories: Environmental Studies, Urban Studies, Ecology, Water Resources, Regional Urban Planning, Biodiversity Conservation, Development Studies, and Environmental Engineering. There were 116 articles in the Water Resources category, and a sample of 64 articles in the Regional Urban Planning area was picked. This sample was evaluated in Excel, and a duplicate was eliminated before picking 22 articles based on their keywords, key phrases, titles, and abstracts. The selected works emphasize the confluence of GI with water resources, as well as regional and urban planning.

Scopus filters were used to identify articles and reviews in English from the Environmental Science area (921). Limiting this category to: Urban Planning, Urban Development, Urban Design, and City Planning resulted in a new sample of 219 articles relating to urban planning, 148 of which were transferred to Excel. To continue the research, 32 articles relating to GI, urban planning, and water resources were identified by an analysis of their titles, abstracts, and keywords.

A new cycle was carried out in the Scopus database; from the previously utilized sample of 921 papers, we narrowed the research to the Water management domain (150), looking for articles having an urban planning focus. For this study, 82 papers were chosen using the keywords urban area, land use, sustainable development, urban planning, urbanization, city, and urban development, and 23 were separated. 50 of these 77 publications were chosen for examination due to their relevance to the topic.

Following the findings, further articles were added to the 50 to explain the relationship between the BGI and its intersections with URP, as well as books, theses, and manuals important to the issue. These were derived from a database of prior studies and research, as well as recommendations from academic networks such as ResearchGate, Academia, and Google Scholar. This strategy of continual inclusion ensured that the literature evaluation was thorough and current, reflecting both the evolution of the subject and the most recent additions. Table 1 provides a short overview of the selected articles.

Table 1: Summary of analyzed articles

Reference	Title
Axelsson et al., 2020	Urban policy adaptation toward managing increasing pluvial flooding events under climate change.
Carter et al., 2017	Adapting cities to climate change – exploring the flood risk management role of green infrastructure landscapes.
Conway et al., 2022	Who participates in green infrastructure initiatives and why? Comparing participants and non-participants in Philadelphia's GI programs.
Cousins and Hill, 2021	Green infrastructure, stormwater, and the financialization of municipal environmental governance.
Dean et al., 2022	Accelerating the adoption of water sensitive innovations: community perceptions of practices and technologies to mitigate urban stormwater pollution.
Elderbrock et al., 2020	A guide to public green space planning for urban ecosystem services.
Feltynowski and Kronenberg, 2020	Urban green spaces—an underestimated resource in third-tier towns in Poland.
Fink, 2018	Contrasting governance learning processes of climate-leading and -lagging cities: Portland, Oregon, and Phoenix, Arizona, USA.
Gašparović et al., 2022	Impacts of Zagreb's urban development on dynamic changes in stream landscapes from mid-twentieth century.
Giner et al., 2019	Promoting green infrastructure in Mexico's northern border: The Border Environment Cooperation Commission's experience and lessons learned.
Gougeon et al., 2023	Impact of bioretention cells in cities with a cold climate: modeling snow management based on a case study.
Hamel et al., 2021	Blending ecosystem service and resilience perspectives in planning of natural infrastructure: Lessons from the San Francisco Bay Area.
Hamel and Tan, 2022	Blue–green infrastructure for flood and water quality management in Southeast Asia: Evidence and knowledge gaps.
Hamlin and Nielsen-Pincus, 2020	From gray copycats to green wolves: policy and infrastructure for flood risk management.
Hasala et al., 2020	Green infrastructure site selection in the Walnut Creek wetland community: A case study from southeast
Heck, 2021	Greening the color line: historicizing water infrastructure redevelopment and environmental justice in the St. Louis metropolitan region.
Heim LaFrombois et al., 2022	Planning for green infrastructure along the Gulf Coast: an evaluation of comprehensive plans and planning practices in the Mississippi-Alabama coastal region.
Hoover et al., 2021	Environmental justice implications of siting criteria in urban green infrastructure planning.

J. Chen et al., 2024	Optimization of the integrated green–gray–blue system to deal with urban flood under multi-objective decision-making.
Johns, 2019	Understanding barriers to green infrastructure policy and stormwater management in the City of Toronto: a shift from grey to green or policy layering and conversion?
Kooy et al., 2020	Nature Based Solutions for urban water management in Asian cities: integrating vulnerability into sustainable design.
Kvamsås, 2021	Addressing the adaptive challenges of alternative stormwater planning.
Kvitsjøen et al., 2021	Intensifying rehabilitation of combined sewer systems using trenchless technology in combination with low impact development and green infrastructure.
Lee and Kim, 2023	Green space ecosystem services and value evaluation of three-dimensional roads for sustainable cities.
Liu and Wu, 2022	Scenario analysis in urban ecosystem services research: Progress, prospects, and implications for urban planning and management.
Matsler et al., 2021	A ‘green’ chameleon: Exploring the many disciplinary definitions, goals, and forms of “green infrastructure”.
Matsler et al., 2023	Institutionalizing barriers to access? An equity scan of green stormwater infrastructure (GSI) incentive programs in the United States.
McFarland et al., 2019	Guide for using green infrastructure in urban environments for stormwater management.
Mei et al., 2018	Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed.
Morris and Tippett, 2023	Perceptions and practice in Natural Flood Management: unpacking differences in community and practitioner perspectives.
Muller and Mitova, 2023	The Hardening of the American Landscape: Effects of Land Use Policy on the Evolution of Urban Surfaces.
Nasr and Potteiger, 2023	Spaces, systems and infrastructures: From founding visions to emerging approaches for the productive urban landscape.
Nguyen et al., 2019	Implementation of a specific urban water management - Sponge City.
Probst et al., 2022	Blue Green Systems for urban heat mitigation: mechanisms, effectiveness and research directions.
Reu Junqueira et al., 2023	Developing and testing a cost-effectiveness analysis to prioritize green infrastructure alternatives for climate change adaptation.
Rojas et al., 2022	Assessment of the flood mitigation ecosystem service in a coastal wetland and potential impact of future urban development in Chile.
Schubert et al., 2017	Implementation of the ecosystem services approach in Swedish municipal planning.
Simpson and Winston, 2022	Effects of land use on thermal enrichment of urban stormwater and potential mitigation of runoff temperature by watershed-scale stormwater control measures.
Sinnett et al., 2018	The translation and use of green infrastructure evidence.
Song et al., 2024	Perspective swap from central Europe to east Asia: How relevant is Urban Environmental Acupuncture in small-scale green space development in the context of the republic of Korea?
Staddon et al., 2018	Contributions of green infrastructure to enhancing urban resilience.
W. Chen et al., 2024	Multi-objective decision-making for green infrastructure planning: Impacts of rainfall characteristics and infrastructure configuration.
Walker, 2021	Engineering gentrification: urban redevelopment, sustainability policy, and green stormwater infrastructure in Minneapolis.
Wang et al., 2023	Green infrastructure optimization considering spatial functional zoning in urban stormwater management.
Wilfong et al., 2023	Shifting paradigms in stormwater management – hydrosocial relations and stormwater hydrocitizenship.

Wilfong et al., 2022	Diffusing responsibility, decentralizing infrastructure: hydrosocial relationships within the shifting stormwater management paradigm.
Willems et al., 2020	How actors are (dis)integrating policy agendas for multi-functional blue and green infrastructure projects on the ground.
Woznicki et al., 2018	Effectiveness of landscape-based green infrastructure for stormwater management in suburban catchments.
Zheng and Barker, 2021	Green infrastructure and urbanisation in suburban Beijing: An improved neighbourhood assessment framework.
Zuniga-Teran et al., 2019	Challenges of mainstreaming green infrastructure in built environment professions.

Source: Authors, 2024.

FINDINGS ON BLUE INFRASTRUCTURE IN THE RELATIONSHIP BETWEEN GREEN INFRASTRUCTURE AND URBAN AND REGIONAL PLANNING

The authors view the incorporation of GI into urban planning as a tool for urban regeneration in the pursuit of sustainability and social advantages. GI is viewed as a strategy capable of increasing city resilience in the face of climate change and rapid urbanization. This includes the use of GI in water management.

Rainwater management is linked to GI practices, such as food production in urban areas, as another resilience approach (NASR and POTTEIGER, 2023). Other suggestions, such as converting roads into green spaces (LEE and KIM, 2023) and lawn areas into planting areas (ELDERBROCK et al., 2020), are seen as solutions for increased rainwater infiltration, biodiversity, connectivity, and landscape aesthetics.

Authors suggest renaturalizing water systems to mimic natural drainage and restore aquatic ecosystems (GOUGEON et al., 2023; MATSLER et al., 2021), as well as using natural infrastructure, or BGI, to combat flooding (HAMEL et al., 2021) and promote equity and environmental justice (HOOVER et al., 2021).

MULTIFUNCTIONAL GI SERVICES

As previously declared, the authors reinforce this multifunctionality perspective by suggesting that GI be used to provide a variety of services, including flood control, air quality improvement, and recreational opportunities, as well as integrating historically underrepresented and vulnerable communities and involving them in its design (HASALA et al., 2020). The incorporation of GI (both its green areas that contribute to drainage and its blue infrastructure) into the URP has the potential to promote social justice by dissolving historical inequalities and systemic racism in urban planning (HOOVER et al., 2021), protecting communities from flooding and a lack of stormwater management, and promoting equity (CONWAY et al., 2022).

These communities can be revitalized with public funding by incorporating small-scale green infrastructures, such as green roofs (SONG et al., 2024), as well as other Nature-based Solutions (NbS) (LIU and WU, 2022) in degraded and vulnerable areas (HASALA et al., 2020), which promote human well-being, restoring people's connection to nature (SINNETT et al., 2018). Several authors (KOOY et al., 2020; KVAMSÅS, 2021; ROJAS et al., 2022; WILFONG et al., 2023) advocate for the use of NbS, which are part of the GI range (FLETCHER et al., 2014), regardless of scale, in addition to observation of Ecosystem Services (ES), or ecological services, in the integration of GI and UP.

According to the studies in this sample, for these initiatives to be successful, regulation and the development of clear standards for their implementation are necessary. Cities such Malmö, Sweden (SCHUBERT et al., 2017) with green roofs and green spaces or constructed wetlands as at Krueger National Park, South Africa (STADDON et al., 2018) demonstrate that regulations requiring the GI inclusion in new developments can ensure that it is integrated into urban development plans sustainably. However, Policy makers should be included in the research process when research findings are made so that they can be translated into policy. Other gaps must be addressed, including a lack of longitudinal research on health outcomes from GI and a lack of emphasis on design (SINNETT et al., 2018). In addition to water concerns, other studies propose for the multifunctionality and holistic integration of GI into urban initiatives, beginning with land use planning.

LAND USE, URBAN PLANNING AND GI

For greater success, GI should be included from the start of urban development projects, or from scenarios analysis, considering the distinct requirements of each location (LIU and WU, 2022). Some authors in the sample study suggest for the incorporation of GI into urban and regional planning, with direct or indirect reference to land use policy (Table 2).

Table 2: GI in land use and planning

Integration of GI in land use planning and policies
Taking advantage of land use as a planning tool, considering everything from small-scale, such as private properties, to large-scale, such as the entire urban landscape. Integration of GI into traditional systems to manage pluvial flooding events and face climate crises. GI controlling the forms and responses to urban growth. (AXELSSON et al., 2020)
GI planning prioritizing areas with greater water absorption capacity. (J. CHEN et al., 2024)
GI with inventorying, to protect and enhance green spaces, avoid uncontrolled urbanization and consequent loss of resources and ES. Connection between urban areas, agricultural and natural spaces. (FELTYNOWSKI and KRONENBERG, 2020)

Municipal legislation and strategic locations enabling a paradigm change in urban planning to better stormwater management: GI-friendly Urban Development code. (GINER et al., 2019)
Valorization of wetlands and their ES in land use. (HAMLIN and NIELSEN-PINCUS, 2020)
Integrating local community knowledge and needs and hydrological modeling into land use planning. (HASALA et al., 2020)
GI incorporated into planning not only for maximize benefits, stormwater management, air quality, but for promotion of accessible green spaces, environmental justice and equity, and to combating gentrification. (HOOVER et al., 2021)
The scenario analysis with land use, ES and their projections, evaluating the impact of the kind of land use on urban, agricultural and natural areas and their ES. (LIU e WU, 2022)
Research indicates that there is a hidden potential for climate adaptation in general land use policies. (MULLER and MITOVA, 2023)
Local features should be considered while planning alongside GI. (PROBST et al., 2022)
Division of urban areas into functional zones for specific GI, flood risk and runoff control solutions. (WANG et al., 2023)

Source: Authors, 2024.

In land use studies, green areas and their connectivity potential should be prioritized in order to maximize ecosystem services and maintain city resilience in the face of climate change (LIU and WU, 2022). Furthermore, the use of GI in conjunction with land use policies in urban and regional planning allows for the construction of various scenarios, their analyses, and the projection of responses, such as impacts on urban, agricultural, and natural areas as a result of their developments (LIU and WU, 2022).

This potential for land use is rarely discussed in academic literature. Many papers emphasize the significance of incorporating GI into planning, but they do not always address land use in the development of space. In addition to the mention of land use in scenario construction and predictions (LIU and WU, 2022), only one other item in our sample deals more incisively with the problem of using Land Use Planning (or Land Use Management) to dictate urban form in conjunction with BGI. Axelsson et al. (2020) article also examines the use of natural and semi-natural GI systems to achieve greater control over reactions or consequences in the creation and protection of the urban environment against pluvial flooding and heat islands.

The integration of GI with land use policy highlights the need of using this tool to safeguard ecosystems and shift paradigms. For example, stormwater management could be enhanced by increasing mitigation efforts, such as minimizing the increase in impermeable surfaces, and implementing balanced urban densification management techniques to reduce environmental concerns (MULLER and MITOVA, 2023). Moreover, valuing regions such as wetlands and floodplains, which contribute to the hydrological cycle (HAMLIN and NIELSEN-PINCUS, 2020) but its conservation are frequently viewed as a barrier to urban expansion (ROJAS et al., 2022).

INSERTION OF GI IN LAND USE LEGISLATION TO PROMOTE ECOLOGICAL CONNECTIVITY AND SOCIO-ENVIRONMENTAL JUSTICE: ACTORS, SCALE AND LOCAL CHARACTERISTICS

Ecological connectedness is critical to the efficacy of green infrastructure (GI) in urban development, as it promotes ecosystem resilience and enhances environmental quality. The establishment of ecological corridors, or linkages, connects portions of natural ecosystems and urban green areas, ensuring the continuity of ecological processes. These corridors promote species movement and gene exchange across populations, increasing urban biodiversity and aiding in the preservation of natural ecosystems in urbanized areas (HEIM LAFROMBOIS et al., 2022). Floodplain restoration also improves connectivity by interconnecting with rivers and other bodies of water while encouraging important ecosystem services like flood mitigation and water availability (HAMLIN and NIELSEN-PINCUS, 2020).

Given these themes, connectivity and land use, the authors believe that incorporating GI into urban planning fosters environmental resilience by promoting species mobility and the maintenance of essential ecological processes (HEIM LAFROMBOIS et al., 2022). The establishment of ecological corridors and the restoration of floodplains improve biodiversity and ecosystem services. To make this practicable and successful, they must be incorporated into land use regulations (HAMLIN and NIELSEN-PINCUS, 2020; HOOVER et al., 2021; LIU and WU, 2022; JOHNS, 2019), with a focus on local characteristics and community needs (KOOY et al., 2020; KVAMSÅS, 2021; WILFONG et al., 2022).

Connectivity also needs to be defined in terms of cohesive urban green infrastructure networks, in which various elements such as green roofs, bioswales, and rain gardens are interconnected and function together. Using Geographic Information Systems (GIS) and established theories of landscape connectivity, it is possible to detect fragmentation-prone areas and prioritize actions that reconnect these green elements (ZHENG and BARKER, 2021).

While local populations' adoption of these strategies is frequently tied to the recreational value and accessibility of these new green areas, planning professionals typically emphasize on the advantages to biodiversity and wildlife (MORRIS and TIPPETT, 2023). This integrated method increases ecological resilience, allowing ecosystem functions to be maintained even in complex urban contexts.

By reconciling GI with urban land use legislation, productive and integrative networks are developed that connect various land uses and BGI initiatives, hence increasing the positive impact of GI. Its outcomes go beyond sustainability with connectedness and gains from ecosystem services; they create a resilient urban environment capable of dealing with social as well as ecological stresses. The addition of community gardens and urban gardens associated with urban agriculture to this context maximizes social benefits while improving community inclusion in the planning process (NASR and POTTEIGER, 2023).

Green infrastructure (GI) implementation in urban planning, when combined with land use policies, necessitates a holistic approach. Hamlin and Nielsen-Pincus (2020) mentions the 3 dimensions of infrastructure: technological, social and ecological and among the political interventions that encourage the use of GI, the authors mention the change of rules such as accounting regulations, including non-monetary values of nature. About these values, for example, perceptions of wetlands have shifted from expansion places for real estate market to environmentally valued assets with the potential to reduce reliance on grey infrastructure. This shift protects wetlands rather than indiscriminately developing them, hence supporting their environmental functions in stormwater management and responding to natural hazards (JOHNS, 2019; ROJAS et al., 2022). Hoover et al. (2021) add that green infrastructure should be incorporated into land use policies as a major component of urban planning to guarantee that green spaces, and NbS are integrated into the development process rather being viewed as afterthoughts. Cities can manage their water resources more effectively and reduce the effects of impermeable surfaces by developing such land use rules, using modeling practices to assess urban surface change (MULLER and MITOVA, 2023).

To enable effective implementation, both local factors and urban regions' historical legacies must be considered into account. The authors underline that GI planning must be adapted to the climatic circumstances and physical characteristics of the site, such as urban surfaces and sensitivity to flooding, utilizing hydrological modelling and local knowledge (KOOY et al., 2020; MCFARLAND et al., 2019), echoing Ian McHarg's method . This integrated approach allows for more appropriate land use decisions based on the environmental and social characteristics of each location, ensuring that green infrastructure meets the community's individual needs. However, in some developing countries, the partnership between institutions and GI initiatives can be influenced by historical practices of institutionalized racism, as occurred in American cities, demonstrating that the impacts of

GI can vary significantly depending on how and where it is implemented, and may, in certain contexts, perpetuate socio-spatial inequalities (HECK, 2021; HOOVER et al., 2021).

Urban governance and municipal regulations play an important role in prioritizing and managing green infrastructure. The creation of municipal regulations based on design guidelines fosters a regulatory environment that promotes the equitable and efficient implementation of GI (STADDON et al., 2018; WALKER, 2021). To reap the most benefits from GI, urban areas must be divided into functional zones, such as flood risk control zones.

In terms of governance and policy formation, the sample demonstrates two distinct approaches in the United States, where local political ethos drives land use policies and prioritizes sustainable projects in Portland and Phoenix. While Portland adopts a progressive and integrated strategy, Phoenix, which focuses on economic development and minimal government interference, promotes efficiency above sustainability (FINK, 2018).

Participatory initiatives, which involve the public in design, implementation, and monitoring, play an important role in the acceptability of new green spaces; this social involvement maximizes both social and environmental advantages (FINK, 2018; NASR and POTTEIGER, 2023; SONG et al., 2024). Unlike public participation, ecological interconnectedness and land use receive minimal attention in the sample.

INSTITUTIONAL COLLABORATION, GOVERNANCE, POPULAR PARTICIPATION AND SOCIAL JUSTICE IN THE IMPLEMENTATION OF GI

The multidisciplinary and multiscale nature, combined with holistic approaches, improves the implementation of GI. Technical and social barriers are overcome through collaboration among planners, researchers, and professionals from various fields (ecology, engineering and urban planning) in order to develop more effective urban solutions, mitigate problems such as flooding, restore ecosystems, and improve the quality of urban life (HAMEL et al., 2021; HAMLIN and NIELSEN-PINCUS, 2020; MATSLER et al., 2021; PROBST et al., 2022; ZUNIGA-TERAN et al., 2019). BiodiverCity[5] and other collaborative programs demonstrate the good impact of inter-institutional cooperation in fostering biodiversity and extending urban green areas (SCHUBERT et al., 2017).

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[5] The project aimed to promote biodiversity and increase sustainability in urban areas by identifying new approaches, collaborating with institutions and businesses, and incorporating ES into urban design (SCHUBERT et al., 2017).

Working collaboratively, municipal agencies responsible for urban planning, water, and the environment can make it easier to develop integrated solutions that combine green and blue infrastructures to promote urban resilience (KVAMSÅS, 2021). Efficient communication among involved professionals, such as engineers and planners, ensures the technical validity of suggestions (GINER et al., 2019). When considering the community's needs and preferences, the acceptance and involvement of these initiatives increases. Popular participation in decision-making results in practices that are adaptable to local demands, strengthens the legitimacy of initiatives (HEIM LAFROMBOIS et al., 2022; KVAMSÅS, 2021), increases confidence in the effectiveness of the measures adopted, with the learning-through-doing approach (MORRIS and TIPPETT, 2023), promotes a sense of belonging and shared responsibility, and encourages the collaborative creation and maintenance of green spaces (SONG et al., 2024).

Active community participation in the design and implementation (ELDERBROCK et al., 2020), can ensures the success and equitable distribution of GI interventions. Giving a greater voice to residents and promoting bottom-up initiatives even in transient neighborhoods (ZHENG and BARKER, 2021). Raising awareness and educating the public about the importance of GI is necessary for reducing pollution and the effects of climate change. New technologies help to communicate impacts and visualize them in the local landscape, even those previously invisible such as pollution, contributing to the community's understanding of techniques and possible solutions. (DEAN et al., 2022). Supporting grassroots activities, training the population, and raising knowledge about the benefits of GI are critical for encouraging local acceptance of BGI, boosting citizen engagement, and supporting decentralized decision-making. After decades of centralized management, a reframing of how individuals view their responsibilities and duties to manage stormwater is required (WILFONG et al., 2023). The meaning of BGI varies depending on the actors involved, but its goals bring people together (WILLEMS et al., 2020).

Portland is an example of a participatory strategy that uses collaborative decision-making to develop innovative and inclusive climate strategies (FINK, 2018). Phoenix has adopted the opposite, centralized and more typical top-down governance approach, which focuses on efficiency and corporate interests, making its climate initiatives technocratic and reactive, more concerned with immediate economic requirements than with long-term sustainability. Cultural and political differences can have an impact on governance, as these two examples demonstrate (FINK, 2018).

Innovation in governance models is required to ensure that GI is fully incorporated into urban planning, both top-down and bottom-up, hence facilitating city adaptation to climate change (STADDON et al., 2018). Furthermore, the adoption of GI must be complemented by laws to prevent gentrification, which is frequently associated with urban revival. Regulations on real estate speculation, rent control, and support for cooperative housing are proposed to guarantee that the advantages of GI are dispersed fairly and do not worsen present (WALKER, 2021) or historical inequities (HOOVER et al., 2021).

In St. Louis (USA), for example, the legacy of racial segregation and discriminatory planning practices has resulted in considerable inequities in infrastructure provision and investment (HECK, 2021). Public consultations and workshops can ensure that these minority and historically marginalized communities are served, fostering more equitable and inclusive urban development (HOOVER et al., 2021). The participatory processes enable the population to express their views and identify priority areas for GI interventions, addressing specific environmental issues and promoting solutions that reflect local concerns (ELDERBROCK et al., 2020). Low-income communities can be integrated through incentive programs such as subsidies and tax exemptions, guaranteeing equitable benefit distribution.

The diversity of hydrosocial relationships[6] (WILFONG et al., 2023), including diverse perspectives on the decentralization of stormwater management, is essential for GI solutions to work as catalysts for social justice and urban fairness, rather than only meeting immediate demands (WILFONG et al., 2022). To include GI within a larger context of sustainability, urban planning strategies that prioritize environmental quality and social fairness are required (ZHENG and BARKER, 2021). To accomplish this, residents' installation and maintenance costs must be reduced, removing financial barriers that exclude disadvantaged populations, promoting social cohesion, and improving quality of life (KOOY et al., 2020; MATSLER et al., 2023; WALKER, 2021).

Implementing GI to address contemporary environmental and social challenges requires not only strong inter-institutional collaboration, but also the simplification of

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[6] Decentralization of rainwater management and promotion of hydrocitizenship, or enhanced citizen responsibility, achieved by understanding the roles involved and the function of public authorities, as well as one's own position as a citizen while accepting obligation (WILFONG et al., 2023).

administrative processes to direct investments in an inclusive manner, increase program accessibility, avoid gentrification, and promote integrated management of green areas and urban waters (MATSLER et al., 2023; WALKER, 2021; WILFONG et al., 2022). Even in the private sector, measures should be devised to encourage landowners to make their land accessible for the establishment of green spaces (SONG et al., 2024), thereby strengthening community connections. Both GI and BI are considered to address the cultural and aesthetic demands of urban people, helping to the establishment of pleasant public areas and the enhancement of historical and landscape heritage (GAŠPAROVIĆ et al., 2022).

To be effective, public engagement must encourage a culture shift that recognizes the importance of GI in urban planning. In Johns (2019) research, it is clear how much knowing GI and its roles in UP facilitates the advancement of its implementation, as in his research where interviewees were people involved in green infrastructure policies, there was a consensus that municipalities need to do more about GI in stormwater management. Interdisciplinary and collaborative involvement among multiple stakeholders, including local communities, NGOs, government agencies, and the private sector, is important for developing a shared understanding of the benefits of GI (MCFARLAND et al., 2019; WILLEMS et al., 2020). This is feasible through grassroots measures like education and awareness-raising activities, which empower citizens and encourage voluntary adoption of sustainable behaviors (FINK, 2018; MORRIS and TIPPETT, 2023). Coordination between the public and private sectors, NGOs, and local communities promotes knowledge sharing and resource optimization, while academic institutions' participation contributes to information exchange and the identification of best practices to be implemented (HEIM LAFROMBOIS et al., 2022; JOHNS, 2019) in a social learning environment fostered by continuous stakeholder engagement (HAMEL et al., 2021).

Even in monitoring, the participatory approach to GI oversight proves essential for aligning the perceptions of the numerous stakeholders engaged and ensuring equitable resource distribution, looking for solutions beyond rainfall problems (AXELSSON et al., 2020), or to nature resources management measures (MORRIS and TIPPETT, 2023). As previously said, community legitimate participation should be addressed throughout the process, from planning to ongoing operations, with tactics adjusted to reflect results and developing requirements (MATSLER et al., 2023).

THE SIGNIFICANCE OF SCALE AND LOCAL FACTORS

Authors also highlight the role of GI in urban planning in resolving accessibility issues (MORRIS and TIPPETT, 2023) and other problems caused by fast urbanization (ZHENG and BARKER, 2021). They emphasize the need for working at small scales (WILFONG et al., 2022), or neighborhood scale (ZHENG and BARKER, 2021), to better understand local characteristics and, according to Wilfong et al. (2022), to more efficiently mimic natural processes such as infiltration and evapotranspiration. They point out that GI should be used to manage stormwater and improve water quality, especially in areas vulnerable to flooding (GAŠPAROVIĆ et al., 2022) or in regions with extreme weather events (GOUGEON et al., 2023).

Some academics emphasize the need to focus on geography's specificities and local peculiarities. Following the example of snowmelt water, bioretention cells are proposed as a strategy for improving it by lowering contaminants from precipitation and improving urban environmental quality (GOUGEON et al., 2023; KOOY et al., 2020; MORRIS and TIPPETT, 2023; NGUYEN et al., 2019; WALKER, 2021). In addition to water quality, authors emphasize the relevance of water quantity, highlighting the necessity to combine GI policies with current gray infrastructure schemes, as well as coastal cities (JOHNS, 2019; ROJAS et al., 2022).

Success in the sustainability and maintenance of GI application in the UP is dependent not only on local characteristics (CARTER et al., 2017; DEAN et al., 2022; ZHENG and BARKER, 2021), but also on the demands of the communities included in the planning, particularly in the Global South that faces severe challenges (ZUNIGA-TERAN et al., 2019). To achieve this, new statutes that stimulate the adoption of GI must be developed, regulations, as well as financial resources reallocated to prioritize investments aimed at city sustainability and resilience (AXELSSON et al., 2020; COUSINS and HILL, 2021; WALKER, 2021). Promoting education and knowledge about GI can mobilize community support and ensure that projects satisfy their requirements (DEAN et al., 2022), preventing green gentrification (WALKER, 2021), as well as improve their acceptance, resulting in a new relationship of citizen responsibility (WILFONG et al., 2023).

TOOLS, APPROACHES, AND BARRIERS IN THE APPLICATION OF GI

TOOLS TO SUPPORT GI DESIGN

Research and tools have been developed to improve the implementation of GI. For example, the research by Wang et al. (2023) on the optimization of green infrastructure, gray infrastructure, and blue infrastructure, based on spatial functional zones, suggests that this approach offers a more reliable and adaptable solution for urban stormwater management, while also serving as a reference for the design and layout of GI in urban areas. This approach can be accompanied by tools developed by others authors, such as: the Green Infrastructure Cost-Effectiveness Rating Index (GICRI)[7] (REU JUNQUEIRA et al., 2023), a tool that can help decision-makers prioritize investments in GI, informing where and how to implement these solutions more effectively, and a spatial configuration tool for GI more a multi-objective optimization tool[8] developed by W. Chen et al. (2024).

With a focus on BI, this tool examines the hydrological relationships between various types of green infrastructure, including green roofs and permeable pavements. It aims to determine the optimal configuration of green infrastructure in a target area, considering water efficiency and costs throughout the life cycle, emphasizing the importance of considering the specifics of the location where GI systems will be implemented, as well as suggesting the use of NbS in urban water management (W. CHEN et al., 2024).

SPECIFIC TECHNIQUES FOR APPLYING GI IN WATER MANAGEMENT

The sample also includes works that address the topic in a more technical way and engineering-focused manner than urban planning, highlighting the importance of assessing the interactions between the various structures and systems employed in water management. However, while designing the landscape with GI, they follow the same reasoning as authors who are more focused on urban and regional planning. These authors take into consideration other factors such as location, hydrological characteristics, and land use type to improve the effectiveness of GI implementation (W. CHEN et al., 2024; MCFARLAND et al., 2019), integrating green, blue, and gray infrastructures, maximizing

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[7] It helps in prioritizing investments in GI, taking into consideration climate scenarios and associated uncertainties, and seeking assertiveness in implementation based on analyses that account for projected variations in climate circumstances, such as rainfall frequency and intensity. In their essay, the authors address the importance of innovative and proactive approaches to flood risk management, in which blue infrastructure can play a significant part (REU JUNQUEIRA et al., 2023).

[8] The tool combines the Storm Water Management Model (SWMM) and the Strength Pareto Evolutionary Algorithm (W. CHEN et al., 2024).

rainwater absorption and reducing surface runoff (J. CHEN et al., 2024), and mitigating thermal pollution that degrades aquatic ecosystems (SIMPSON and WINSTON, 2022).

In this collection of studies that focus on point-of-use GI approaches, vegetated swales and other localized stormwater control practices are recommended for reducing runoff volume and flow rate in suburban and neighborhood-scale catchments, providing ecosystem services (WOZNICKI et al., 2018). However, studies show that decentralized Stormwater Control Measures (SCMs) are more effective than traditional infrastructure (curb-and-gutter systems) in rainfall events of less than 20 mm, which are more frequent, but may not be sufficient when not integrated with other infrastructure in larger events (WOZNICKI et al., 2018). Studies also suggest that SCMs may not provide sufficient treatment to protect coldwater ecosystems from urban development, requiring impervious area limitation and the use of LIDs among other strategies (SIMPSON and WINSTON, 2022).

Three terms with a greater focus on water resources are found in the sample: Blue Green Systems (BGS), Integrated Green-Gray-Blue System (IGGB), and Sponge Cities (SCP). In the application of BGS, green and blue elements (vegetation and water) are combined to maximize ecosystem services and improve connectivity between natural spaces, mitigating urban heat and providing multiple environmental benefits (PROBST et al., 2022). The IGGB for stormwater management proposes a model for assessing the interaction of green-gray-blue infrastructures to determine the spatial arrangement that maximizes rainwater absorption, minimizing surface runoff, increasing drainage capacity and improving natural water circulation in urban areas (J. CHEN et al., 2024). The SCP Program was launched by the Chinese government, associating traditional water management techniques with the LID concept (CHIKHI et al., 2023).

SPONGE CITIES AND LIFE CYCLE COST ANALYSIS OF GI

Sponge cities provide an interesting example of the link between urban development and water supplies. The Sponge City Program (SCP) seeks to integrate urban water management not just to reduce floods, but also to improve water quality, recharge groundwater, expand green space and mitigate greenhouse gas emissions, while avoiding water and soil pollution. The application of GI is one of the main principles of Sponge Cities (NGUYEN et al., 2019). The economic viability and effectiveness of GI in flood prevention while planning sponge cities may be validated using hydrological modeling (Storm Water Management Model - SWMM)[9] (MEI et al., 2018).

Analysis of the life cycle costs of GI solutions must be conducted for ensuring investment sustainability and promoting long-term benefit management strategies. Collaboration among societal sectors (KVITSJØEN et al., 2021) and local regulations according to hydrology, climate and soil characteristics (NGUYEN et al., 2019) is essential for successful and sustainable GI initiatives in cities. Strategic planning of an Integrated Stormwater Management System (ISMS) incorporating GI and LID technologies would optimize its benefits while lowering flood risks. Using intense GI in non-extreme events can minimize flood depth and runoff speed (KVITSJØEN et al., 2021).

CHALLENGES IN IMPLEMENTING GI IN URBAN AND REGIONAL PLANNING

According to the authors, there are financial, institutional, social and technical barriers (Table 3) that hinder the implementation of GI and the adoption of sustainable practices in the management of water resources in urban environments.

Table 3: Barriers in implementing GI in URP

Barriers	Authors and descriptions
Financial	Lack of adoption of stormwater fees and financing to comply with regulations, and renew aging water, sewer, and stormwater infrastructure. (COUSINS and HILL, 2021); Stormwater management fees acceptance (JOHNS, 2019); Inequalities in investment in water infrastructure (KOOY et al., 2020); Financial barriers as property ownership that exclude underserved communities (DEAN et al., 2022; MATSLER et al., 2023), also constituting a social barrier; Difficulty in quantifying benefits of GI, weakening the economic case and limited municipal resources, inhibiting investment (REU JUNQUEIRA et al., 2023); Lack of information on monetization and cost-benefit of GI for property developers, engineers, and local authorities (SINNETT et al., 2018).
Institutional	History of disproportionate investments in gray infrastructure (JOHNS, 2019); Lack of community participation and disconnection from the identity of the place can hinder the acceptance and implementation of GI (HAMLIN and NIELSEN-PINCUS, 2020); Environmental injustices and disparities in access to water services based on race and geographic location (HECK, 2021), an institutional and social barrier;
Barriers	**Authors and descriptions**
Institutional	Political decision-making processes that do not prioritize environmental considerations or the long-term benefits of GI (REU JUNQUEIRA et al., 2023); Centralized and top-down governance models (WILFONG et al., 2023).

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[9] The Storm Water Management Model (SWMM) was designed by the United States Environmental Protection Agency (EPA) with the goals of reducing runoff through infiltration and retention, as well as reducing discharges that impair aquatic bodies. It may assess gray infrastructure stormwater management measures, such as pipes and storm drains, and is an effective tool for developing cost-effective green/gray hybrid stormwater control systems (US EPA, 2014).

Social	Barriers to participation, such as costs and limited space, require inclusive strategies (CONWAY et al., 2022); Reliance on stakeholder perceptions to identify strategies that overcome challenges and maximize benefits in GI implementation (ELDERBROCK et al., 2020); In co-benefit analysis, runoff reduction is often considered at the expense of other benefits, such as water quality, recreation, and public health (REU JUNQUEIRA et al., 2023); Gentrification generated by real estate appreciation due to aesthetic improvements and other gains from GI (WALKER, 2021).
Technical	Regulatory and legislative barriers, bureaucratic structuring, that can hinder the implementation of innovative stormwater management strategies. Complex regulations as cities grows and climate uncertainties that require adaptations (AXELSSON et al., 2020); Challenges in integrating with existing infrastructure (COUSINS and HILL, 2021); Dependence on perceptions about the suitability of water-sensitive technologies that influence their acceptance and the variations required due to local climatic characteristics, aesthetics and personal needs and values (DEAN et al., 2022); Lack of awareness of the importance of green spaces in public health hinders the conviction of decision-makers in the integration of GI in urban planning (GINER et al., 2019); Lack of public awareness by planners and policymakers about the role of GI in quality of life and mitigation of inequalities, promoting public awareness (HOOVER et al., 2021); Inequalities in water infrastructure and political complexity that influence the effectiveness of natural solutions (KOOY et al., 2020); Uncertainty about the hydrological performance of GI that generates resistance and limits its widespread adoption (KVAMSÅS, 2021); Variation of terminology and concepts according to different geographic regions alters its understanding and implementation, in addition to local characteristics and cultural contexts; generating different research focuses, methodologies and efficiency metrics that may not be universally applicable (MATSLER et al., 2021); Climatic and socioeconomic uncertainties make it difficult for policymakers to plan storm water management systems (MEI et al., 2018); Discrepant perceptions between professionals and the community impact sustainability due to the lack of confidence in the suggested technical solutions (MORRIS and TIPPETT, 2023); A lack of understanding of heat sources and sinks within cities and local climate zones, as well as the creation of high spatial and temporal resolution urban heat maps (PROBST et al., 2022); Lack of information about the technical and economic feasibility of GI alternatives, especially in retrofitting areas. Gaps in the analysis of construction and maintenance costs of different types of GI and their effectiveness in precipitation management (REU JUNQUEIRA et al., 2023); Low adoption of GI due to local implementation obstacles (WILLEMS et al., 2020).

Source: Authors, 2024.

The need for coordination between different administrative levels of government, the development of new policy instruments specific to the integration of GI into grey infrastructure, and the reallocation of traditionally allocated investments, as well as the removal of institutional barriers, continue to be major challenges in the transition from grey to green. Collaboration across NGOs, the public, and corporate sectors can achieve a culture shift by increasing capacity and understanding of the benefits of GI, involving communities and stakeholders, and increasing acceptability of proposed solutions (JOHNS, 2019).

DISCUSSION

Green infrastructure (GI) is viewed by the authors as the key to addressing contemporary urban difficulties, fostering multifunctionality and resilience at many scales and settings. Among the proposed solutions, the use of GI in urban planning has proven to be a viable option for tackling water management, environmental sustainability, and equity in society.

Several options for increasing rainwater infiltration are suggested, including the conversion of degraded urban areas into multi-use and recreational places, green roofs, and vegetated swales. These enhance water quality and boost ecosystem services in urban environments (HAMEL and TAN, 2022; MCFARLAND et al., 2019; MORRIS and TIPPETT, 2023; WOZNICKI et al., 2018). Decentralized stormwater control measures (SCMs) are particularly effective during moderate precipitation events, helping to mitigate consequences in vulnerable locations created by the pressure of urban development (WOZNICKI et al., 2018).

The planning of sustainable roads infrastructure as in Korea (LEE and KIM, 2023) and other linear infrastructures with GI seeks to integrate ecological connectivity and urban functionality, as seen in ‘renaturalizing’ water systems and increasing biodiversity in dense urban areas (GAŠPAROVIĆ et al., 2022). The implementation of these methods emphasizes the role of GI in restoring natural processes and minimizing the difficulties caused by disorderly urbanization.

In addition to hydrological issues, the incorporation of GI into urban and regional planning (URP) is viewed as a tool for social justice and environmental equity. Vulnerable populations, historically affected by a lack of stormwater management, can benefit from implementing even small interventions. Publicly sponsored revitalizations of public spaces, as well as the incorporation of green spaces into urban projects, help to reduce structural disparities (HASALA et al., 2020; STADDON et al., 2018).

The authors also underline the importance of clear regulation and public policy tools for enabling and scaling GI-based solutions (STADDON et al., 2018). Regulations in Toronto (Canada), Basel (Switzerland) and Portland (USA), which require green roofs on new developments, show how local policies can assure successful and long-term implementation (STADDON et al., 2018). To fully realize the promise of GI, policies must be aligned with land use management instruments, with guidance for concentrated growth (MULLER and MITOVA, 2023), supporting more integrated and resilient urban responses, as strategies for coastal and fluvial flooding protection. (AXELSSON et al., 2020).

The development of specific tools, such as the Green Infrastructure Cost-Effectiveness Rating Index (GICRI) and spatial analyses of hydrological configuration, has been proposed as effective strategies for prioritizing investments and identifying opportunities to integrate GI with traditional infrastructures (REU JUNQUEIRA et al., 2023; W. CHEN et al., 2024). This approach emphasizes the importance of considering local circumstances while developing solutions, which improves the environmental, social, and economic benefits of GI.

Some authors investigate the social potential of GI, whilst others do not and instead focus on more technical systems such as tool development, SCMs, BMPs, LID, and NbS implementation. However, there is widespread agreement that GI is establishing itself as a critical component for shifting the paradigms of contemporary urban planning in the pursuit of adaptation, sustainability and equity. American situations of commodification in the processes of appropriation and qualifying of waterfronts, such as Minneapolis (Minnesota), Cincinnati (Ohio), San Antonio (Texas), and Fort Lauderdale, demonstrate gentrification as a significant asset employed by public and private investors (Chevalier, 2004). When examining the group of articles observing the integration between GI and BI in urban planning, different views on their conception and application are revealed, three main approaches emerge.

The first viewpoint emphasizes that GI and BI can be regarded as complimentary or even interconnected systems. Although BI is frequently implicit in the broader scope of green infrastructure, with variable degrees of visibility among writers, urban planning that incorporates both infrastructures is considered critical for achieving urban sustainability and resilience. In this context, NbS or GI must be used as multifunctional networks that contain open spaces and water management systems in order to address issues such as urban water pollution and flooding (DEAN et al., 2022; ROJAS et al., 2022). The role of BI is pointed out as a complementary solution that strengthens GI functions, particularly in water resource management, flood control, and water quality improvement, and although this is widely discussed, the expression BI may not even appear in searches, as in Carter et al.

(2017) or even not appear as GI but Water Sensitive Urban Design (WSUD) as in Dean et al. (2022).

The second also discusses GI and BI as an important strategy for sustainable urban planning. Although the BI is not always explicitly discussed, the great potential of their ES in water and urban management is shown (ELDERBROCK et al., 2020). Nonetheless, their integration with GI is clear, particularly in flood management, water purification, and improving urban quality of life (ELDERBROCK et al., 2020; HAMEL et al., 2021; SINNETT et al., 2018). The interaction between vegetation and water, and its ES (LIU and WU, 2022), supports multifunctional solutions that mitigate floods and regulate the hydrological cycle, while also providing benefits such as improved biodiversity and the construction of recreational spaces (SCHUBERT et al., 2017). This approach also addresses grey infrastructure challenges, including suppression of natural watercourses, highlighting the transformative function of BI in restoring aquatic ecosystems (GAŠPAROVIĆ et al., 2022).

The third viewpoint emphasizes GI and BI as components of a larger urban management system, while focusing more on water-related systems methodologies and approaches. Although significant regions and river basins are considered, specific solutions are explored without the required connectiveness in the design and regeneration of urban and regional planning. The BI, which consists of wetlands, lakes, and urban water bodies, is viewed as an important mechanism for retaining and improving urban water quality (HAMEL and TAN, 2022; J. CHEN et al., 2024). Integration with decentralized solutions, such as LID, is emphasized as a technique for increasing hydrological linkages (W. CHEN et al., 2024) and restoring aquatic ecosystems (SIMPSON and WINSTON, 2022). Authors highlight that this approach not only alleviates traditional drainage systems, but also boosts urban resilience, promoting sustainability and adaptability to future climate change.

When analyzing collaboration between government agencies, institutions, and people participation, social justice is not a strong theme in the sample, but the importance of institutional collaboration is universal. Positive and fluid communication among the agents participating in GI research, planning, and execution, as well as sufficient dissemination, is seen as critical to the long-term success of the project. According to Kambites and Owen (as cited in MELL, 2010), connectedness between people, spaces, and various physical and administrative borders are critical components of good GI planning. However, a non-integrative, or a fragmented planning process makes it difficult to successfully adapt federal policy to the local level (ELDERBROCK et al., 2020; MELL, 2010; WILFONG et al., 2023).

CONCLUSIONS

The presence of the BI and the primary themes of the sample of articles varied, and water resources were not identified as a guiding factor in urban and regional planning. Few papers examined the potential of using BI to drive initiatives at various levels. Its prevalence in the articles examined was more closely related to reactive and mitigation efforts for catastrophes such as floods. The articles could also be divided into subgroups based on themes such as governance, water management in urban planning, environmental justice, urban planning and development related to sustainability challenges, urban ecosystem services, and NbS.

GI is a broad, multidisciplinary concept that, when strategically and holistically incorporated into practice, may address a wide range of urban concerns, from water management and climate change mitigation to human well-being and environmental sustainability. This demonstrates that it is consistent with the UN Sustainable Development Goals (SDGs) for the development of Sustainable Cities and Communities (SDG 11) and Climate Action (SDG 13) (Global Goals, n.d., n.p). Some barriers to its adoption, acceptability, and maintenance are caused by variations in its conception, which can differ depending on geographic region or scientific field of interest.

According to the authors' research, many of these can be overcome by taking into consideration the local context and the individual needs of the communities, thereby helping with its popularization through information and education. This study contributes to the international scientific debate by identifying water management issues that planners, policymakers, and other agents face when developing or regenerating urban and regional areas with GI, in order to mitigate or resolve environmental problems. However, the complexities of these processes highlight the need for additional research on BGI and its socio-environmental impacts, the efficacy of its systems and solutions, governance, and, most importantly, the perception of BI as a driving force in the development of urban and peri-urban spaces. This urgency arises from the current climate challenges.

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