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# Conceptual frameworks for evaluating green infrastructure in urban stormwater management

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## Abstract

This paper presents a comprehensive theoretical framework for evaluating the effectiveness of green infrastructure in urban stormwater management. Sustainable stormwater management practices are essential as cities face increasing challenges from climate change; population growth; and urbanization. Green infrastructure; which includes solutions like green roofs; permeable pavements; and bioswales; offers significant environmental; economic; and social benefits. However; existing evaluation methods often fail to account for the full range of these benefits; particularly in diverse urban settings. The proposed framework integrates environmental; economic; and social dimensions to provide a holistic assessment of green infrastructure projects. By incorporating criteria such as runoff reduction; cost efficiency; social equity; and community engagement; the framework supports more informed decision-making for urban planners and policymakers. The adaptability of this framework to different urban environments; from densely populated cities to suburban areas and varied climatic regions; ensures its broad applicability. The paper also highlights the need for future research to empirically validate the framework's components and refine its metrics to enhance its utility for sustainable urban development.

**Keywords:** Green Infrastructure; Urban Stormwater Management; Environmental Sustainability; Urban Planning; Climate Adaptation; Sustainable Development

## 1. Introduction

Urban stormwater management has become an increasingly critical issue as cities worldwide continue to expand (van Leeuwen, Awad, Myers, & Pezzaniti, 2019). The growth of urban areas, characterized by the proliferation of impervious surfaces such as roads, buildings, and parking lots, has significantly altered the natural hydrological cycle (Ferreira et al., 2021). Instead of rainfall infiltrating the ground, it rapidly becomes surface runoff, leading to various challenges, including flooding, erosion, water pollution, and habitat destruction. These challenges are further exacerbated by climate change, which has intensified the frequency and severity of storm events, thereby increasing the volume and velocity of stormwater runoff. Traditional approaches to stormwater management, which typically rely on gray infrastructure like pipes, sewers, and detention basins, are often inadequate in addressing these multifaceted issues. This inadequacy has led to a growing recognition of the need for more sustainable and resilient solutions, with green infrastructure emerging as a viable alternative (Chang, Lu, Chui, & Hartshorn, 2018).

Green infrastructure refers to practices and technologies designed to manage stormwater close to its source, utilizing natural processes to reduce runoff, enhance water quality, and provide additional environmental and social benefits.

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Unlike conventional gray infrastructure, which primarily focuses on the rapid conveyance and storage of stormwater, green infrastructure integrates vegetation, soils, and other elements to mimic natural hydrological processes. Common examples of green infrastructure include green roofs, permeable pavements, rain gardens, bioswales, and constructed wetlands. These solutions manage stormwater more effectively and offer co-benefits such as urban cooling, enhanced biodiversity, improved air quality, and increased recreational opportunities. The importance of green infrastructure in urban stormwater management has grown considerably, reflecting a paradigm shift towards more sustainable and multifunctional approaches to urban planning and development (Ferreira, Duarte, Kasanin-Grubin, Kapovic-Solomun, & Kalantari, 2022).

Despite the recognized benefits of green infrastructure, evaluating its effectiveness remains a significant challenge, particularly across varied urban settings with different climatic, geographical, and socio-economic conditions. Numerous factors, including design specifications, maintenance practices, local environmental conditions, and community engagement, influence the performance of green infrastructure. Furthermore, the benefits of green infrastructure extend beyond simple hydrological outcomes to include economic, social, and ecological dimensions, making evaluation a complex, multidimensional task (Zuniga-Teran et al., 2020). Current assessment methods often fall short in capturing this complexity, as they focus narrowly on specific performance metrics, such as peak flow reduction or pollutant removal rates, without considering broader contextual factors or the integrated benefits of green infrastructure. As a result, there is a pressing need for a comprehensive framework that can systematically evaluate the effectiveness of green infrastructure in managing urban stormwater while accounting for its multifaceted impacts (Griffin et al., 2020).

A comprehensive framework for evaluating green infrastructure should be based on a set of criteria and metrics encompassing the hydrological and environmental performance of these systems and their economic and social contributions. From a hydrological perspective, key metrics might include reductions in peak flow and runoff volume, improvements in water quality through pollutant filtration, and enhancements in groundwater recharge (Zhang, Xu, & Kanyerere, 2020). These indicators are essential for understanding the primary function of green infrastructure in stormwater management. However, focusing solely on hydrological outcomes overlooks the broader benefits that these systems can provide. Therefore, the framework should also include economic criteria, such as cost-effectiveness, return on investment, and potential savings in gray infrastructure costs. Social metrics, such as community acceptance, aesthetic value, and contributions to public health and well-being, are equally important, as they reflect the capacity of green infrastructure to contribute to urban livability and resilience (Dong, Yi, Yuan, & Song, 2023).

This paper aims to develop such a framework by identifying and integrating the various dimensions that contribute to the overall effectiveness of green infrastructure in urban stormwater management. By doing so, the paper aims to fill a critical gap in the current literature, which often treats green infrastructure in a fragmented manner without fully appreciating its multifunctionality and context-specific performance. The proposed framework will provide a more holistic approach to evaluation, enabling urban planners, policymakers, and stakeholders to make more informed decisions about the design, implementation, and management of green infrastructure projects. Moreover, by establishing clear and comprehensive criteria and metrics, the framework can help standardize evaluation practices, facilitating better comparisons across different projects and settings and promoting best practices.

In developing this framework, the paper will first review existing approaches to evaluating green infrastructure, identifying their strengths and limitations. It will then propose a set of criteria and metrics that reflect the hydrological, environmental, economic, and social dimensions of green infrastructure performance. These criteria will be organized into a conceptual model that illustrates how different factors interact to influence the overall effectiveness of green infrastructure. The model will be designed to be flexible and adaptable, allowing it to be applied in various urban contexts and tailored to specific local needs and priorities. Finally, the paper will discuss the potential applications of the framework in urban planning and policy-making, highlighting how it can support more sustainable and resilient approaches to stormwater management.

## 2. Literature Review

### 2.1. Existing Frameworks and Models

Several frameworks and models have been developed to evaluate green infrastructure, each focusing on different aspects of its performance. Most existing frameworks are primarily hydrological, emphasizing the ability of green infrastructure to reduce stormwater runoff, decrease peak flow rates, and improve water quality. For instance, the U.S. Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM) is widely used to simulate the quantity and quality of runoff and assess the effectiveness of various green infrastructure practices. Similarly, the

Impact Development (LID) models prioritize reducing impervious surfaces and incorporating natural features to manage stormwater closer to its source (Lee, Nietch, & Panguluri, 2018).

Other frameworks, such as the Sustainable Drainage Systems (SuDS) approach used in the United Kingdom, provide a more comprehensive evaluation by considering ecological and social benefits alongside hydrological performance (Oluwayemi, 2021). SuDS encourages using multiple criteria, including biodiversity enhancement, aesthetic improvements, community benefits, and stormwater management. The European Union's Green Infrastructure Strategy also advocates a multifunctional approach integrating environmental, economic, and social benefits. However, the focus remains predominantly on environmental outcomes (Grădinaru & Hersperger, 2019).

Despite these advancements, many existing frameworks tend to adopt a narrow perspective, focusing predominantly on hydrological and environmental benefits while often overlooking the broader socio-economic dimensions of green infrastructure. Furthermore, these models frequently assume uniformity in green infrastructure performance across different urban settings, failing to account for variations in local climatic conditions, soil types, land use patterns, and community needs. This gap underscores the need for more adaptable and context-specific frameworks to evaluate green infrastructure's multifaceted impacts holistically.

### 2.2. Current Criteria and Metrics

The criteria and metrics used to evaluate green infrastructure's performance vary widely depending on the specific objectives of the framework or model. Hydrological metrics are the most common, reflecting the primary goal of green infrastructure: to effectively manage stormwater. Key hydrological criteria include runoff volume reduction, peak flow attenuation, and increased infiltration rates. These metrics are crucial for assessing how well green infrastructure can mimic natural hydrological processes and reduce the burden on conventional gray infrastructure systems (Golden & Hoghooghi, 2018).

Water quality metrics are also widely used, focusing on the ability of green infrastructure to filter pollutants from stormwater (Goonetilleke & Lampard, 2019). Common metrics in this category include reductions in nutrient loads (such as nitrogen and phosphorus), decreases in suspended solids, and removal of heavy metals and other contaminants. These metrics are particularly important in urban areas where stormwater runoff is a major source of pollution to receiving water bodies (Davis, Hunt, & Traver, 2022). While hydrological and water quality metrics dominate the evaluation landscape, there is a growing recognition of the need to incorporate additional criteria that capture the broader benefits of green infrastructure. Economic metrics are increasingly being considered, such as cost-effectiveness, life-cycle costs, and potential savings from reduced reliance on gray infrastructure. For example, some frameworks now include benefit-cost analysis to compare the long-term economic benefits of green infrastructure with traditional approaches (Wang et al., 2023).

Social metrics are also gaining attention, particularly those related to community well-being, public health, and social equity. Metrics such as increased green space availability, enhanced recreational opportunities, improved air quality, and contributions to urban cooling are incorporated into some evaluation frameworks. However, these social metrics are often less rigorously defined and measured than hydrological and water quality metrics, reflecting a relative lack of methodological development in this area (Parish et al., 2019).

### 2.3. Gaps in the Literature

Despite the progress in developing frameworks and models for evaluating green infrastructure, significant gaps remain, particularly concerning integrating environmental, economic, and social dimensions. One major gap is the lack of comprehensive frameworks that fully integrate these three dimensions into a unified evaluation approach. Most existing models focus on a single dimension or, at best, consider two dimensions without adequately addressing the third. For instance, while some frameworks consider both hydrological and ecological outcomes, they often neglect green infrastructure investments' economic and social implications (Venkataramanan et al., 2019).

Another critical gap is the need for more context-specific evaluation approaches that account for the unique characteristics of different urban settings. Current frameworks often adopt a one-size-fits-all approach, assuming uniformity in green infrastructure performance across diverse environments (Arthur & Hack, 2022). However, the effectiveness of green infrastructure can vary significantly depending on local conditions, such as climate, topography, soil type, and community engagement. There is a need for more adaptable frameworks that can be tailored to specific contexts, allowing for more accurate assessments of green infrastructure's performance and benefits (Campbell-Arvai & Lindquist, 2021). Additionally, there is a gap in developing robust social metrics that can capture the full range of social benefits of green infrastructure. While there is increasing recognition of the importance of social benefits, such as improved public health, social cohesion, and enhanced quality of life, these metrics are often poorly defined and inconsistently applied. More rigorous research is needed to develop standardized social metrics and methods for integrating them into comprehensive evaluation frameworks.

Finally, there is a lack of longitudinal studies that assess the long-term performance and benefits of green infrastructure. Most existing studies focus on short-term outcomes, providing limited insight into how green infrastructure performs over time and under varying conditions. Longitudinal studies are crucial for understanding the sustainability and resilience of green infrastructure and for developing frameworks that can guide long-term planning and decision-making (Whitten, 2023).

## 3. Proposed Theoretical Framework

In order to effectively evaluate green infrastructure in urban stormwater management, it is crucial to develop a comprehensive framework encompassing the diverse range of benefits and outcomes associated with these systems. Green infrastructure is unique in its ability to deliver multiple benefits across environmental, economic, and social dimensions, and any robust evaluation framework must capture this multifaceted nature. This section presents a detailed conceptual framework for evaluating green infrastructure, explains the criteria and metrics proposed for assessing its effectiveness, and describes the model's components and how they interrelate to provide a holistic evaluation.

### 3.1. Conceptual Framework for Evaluating Green Infrastructure

The proposed conceptual framework for evaluating green infrastructure in urban stormwater management is based on a multidimensional approach that integrates environmental, economic, and social criteria. The framework is designed to provide a comprehensive assessment of green infrastructure's effectiveness by considering its capacity to manage stormwater and its broader contributions to urban sustainability and resilience. The framework comprises three main components: environmental performance, economic efficiency, and social impact. Each component includes a set of specific criteria and metrics that reflect the diverse benefits of green infrastructure and allow for a nuanced evaluation of its performance across different contexts.

The first component, environmental performance, focuses on the core hydrological functions of green infrastructure, such as reducing stormwater runoff, enhancing water quality, and restoring natural hydrological processes. Key criteria within this component include runoff volume reduction, peak flow attenuation, pollutant removal efficiency, and groundwater recharge. These criteria are essential for understanding how effectively green infrastructure can mimic natural systems and mitigate the adverse impacts of urbanization on the hydrological cycle. Additionally, the environmental component considers biodiversity enhancement and habitat creation, recognizing that green infrastructure can provide critical ecological services in urban environments.

The second component, economic efficiency, evaluates green infrastructure from a cost-benefit perspective, considering both direct and indirect economic impacts. Key criteria in this component include initial capital costs, long-term maintenance and operation costs, cost savings from reduced demand on gray infrastructure, and potential increases in property values due to enhanced urban aesthetics and livability. By incorporating economic metrics, the framework provides a more holistic view of green infrastructure's value, accounting for both the upfront investment and the long-term financial benefits. This component also considers the opportunity costs associated with land use changes, recognizing that green infrastructure may require space that could be used for development or other purposes.

The third component, social impact, assesses the social benefits of green infrastructure, which are often less tangible but equally important for urban sustainability. Criteria in this component include public health benefits, such as improved air quality and reduced urban heat island effects, as well as social equity and community engagement. The framework also considers aesthetic and recreational value, which can enhance residents' quality of life and foster social cohesion. By including social metrics, the framework ensures that the evaluation of green infrastructure accounts for its potential to improve urban livability and promote social well-being beyond its primary environmental and economic functions.

### 3.2. Criteria and Metrics for Assessing Effectiveness

To assess the effectiveness of green infrastructure, the framework employs a set of criteria and metrics tailored to each of the three components. For environmental performance, metrics such as runoff volume reduction (measured in cubic meters per rainfall event), peak flow reduction (measured as a percentage decrease in peak discharge), pollutant removal efficiency (measured in terms of percentage reduction in specific contaminants like nitrogen, phosphorus, or suspended solids), and groundwater recharge rates (measured in cubic meters per year) are used to quantify the hydrological and water quality benefits. Additional metrics, such as the area of habitat created (measured in square meters) and species diversity indices, are included to evaluate the ecological contributions of green infrastructure.

In the economic efficiency component, metrics such as cost-benefit ratio, payback period (measured in years), and lifecycle costs (including both capital and maintenance expenses) provide a comprehensive assessment of the financial implications of green infrastructure investments. Cost savings from reduced stormwater management fees or decreased flood damage (measured in monetary terms) are also considered, along with potential increases in property values (measured as a percentage increase in real estate prices in areas adjacent to green infrastructure projects). These metrics help stakeholders understand the economic viability and return on investment associated with green infrastructure, promoting more informed decision-making in urban planning and development.

The social impact component includes metrics such as improvements in air quality (measured as reductions in particulate matter concentrations), reductions in urban heat island intensity (measured in degrees Celsius), and increases in green space per capita (measured in square meters per person). Additional metrics, such as community satisfaction scores (measured through surveys or interviews) and accessibility to green infrastructure (measured as the percentage of the population within a certain distance from green spaces), are used to assess the social equity and inclusiveness of green infrastructure projects. These metrics provide valuable insights into how green infrastructure can contribute to public health, social cohesion, and overall quality of life in urban areas (Santamouris & Osmond, 2020).

### 3.3. Interrelation of Model Components for Holistic Evaluation

The proposed framework emphasizes the interrelation of its components to provide a holistic evaluation of green infrastructure. Environmental, economic, and social components offer unique insights into green infrastructure's performance. However, it is their integration that truly captures the multifaceted nature of these systems. For instance, a green infrastructure project that effectively reduces stormwater runoff (environmental performance) may also lead to reduced flood damages and lower insurance costs (economic efficiency) while simultaneously providing new recreational opportunities and improving mental health outcomes (social impact).

By interlinking these components, the framework recognizes that the benefits of green infrastructure are not isolated but interconnected, often producing synergistic effects that enhance overall urban sustainability. For example, a bioswale designed to manage stormwater may also serve as a habitat for urban wildlife, improve local air quality, and provide aesthetic value to the community. This way, the framework promotes a more integrated approach to green infrastructure evaluation, encouraging stakeholders to consider the broader range of outcomes and trade-offs associated with different projects.

Furthermore, the framework is designed to be adaptable and flexible, allowing it to be applied across various urban contexts and scales. This adaptability is crucial for addressing the unique challenges and opportunities in different cities, climates, and socio-economic settings. The framework facilitates better comparisons across projects by providing a standardized yet flexible approach to evaluation. It encourages the adoption of best practices in urban stormwater management.

## 4. Application of the Framework in Varied Urban Settings

### 4.1. Application Across Different Urban Environments

Urban environments are highly diverse, with significant variations in density, land use, climate, and socio-economic conditions. These factors can greatly influence green infrastructure's design, implementation, and effectiveness. For densely populated cities, where space is at a premium and impervious surfaces dominate, green infrastructure must be carefully integrated into the existing urban fabric. Here, the framework emphasizes the importance of maximizing multifunctionality—green infrastructure must manage stormwater effectively and provide additional benefits, such as urban cooling, enhanced air quality, and increased recreational space (Zuniga-Teran et al., 2020). Metrics such as runoff volume reduction, pollutant removal efficiency, and improvements in air quality are particularly relevant in these settings, where the primary objective is to mitigate the impacts of dense development on urban hydrology and public health.

In suburban areas, where land is more readily available, and development is less dense, the framework allows for a broader range of green infrastructure solutions, including larger-scale interventions like constructed wetlands, bioswales, and extensive rain gardens. In these settings, the framework can emphasize groundwater recharge, biodiversity enhancement, and social equity metrics (Beecham, Razzaghmanesh, Bustami, & Ward, 2019). Suburban areas often face challenges related to rapid development and increased runoff. However, they also present opportunities for creating interconnected green networks supporting stormwater management and community well-being. Economic metrics such as cost-effectiveness and return on investment are also critical in these settings, where local governments and developers must balance the benefits of green infrastructure against the costs of traditional gray infrastructure solutions (Artmann, Kohler, Meinel, Gan, & Ioja, 2019).

The framework's adaptability is particularly valuable for regions with varying climates—such as arid, temperate, or tropical zones. In arid climates, where water conservation is a priority, the framework can focus on metrics emphasizing water reuse and efficiency, such as stormwater capture and storage for irrigation or other non-potable uses. Green infrastructure in these regions must be designed to withstand extreme temperatures and limited rainfall, often incorporating drought-resistant vegetation and materials that minimize evaporation. In contrast, in tropical climates, where intense rainfall and frequent storms are common, the framework can prioritize metrics related to flood mitigation, peak flow reduction, and resilience to extreme weather events. The framework ensures that green infrastructure solutions are effective and contextually appropriate by tailoring the evaluation criteria to the specific challenges and opportunities of different climates.

### 4.2. Case Examples and Hypothetical Scenarios

To illustrate the application and adaptability of the proposed framework, consider the case of a densely populated city such as New York City. In this urban environment, space is limited, and the impervious surfaces significantly increase stormwater runoff, contributing to frequent flooding and combined sewer overflows (CSOs) (Botturi et al., 2021). The proposed framework can guide the evaluation of various green infrastructure projects implemented throughout the city, such as green roofs, permeable pavements, and rain gardens. Metrics like runoff volume reduction, peak flow attenuation, and pollutant removal efficiency are used to assess the environmental performance of these projects. At the same time, economic metrics such as cost savings from reduced CSO events and social metrics like improved urban aesthetics and increased recreational opportunities are also considered. The framework's holistic approach enables city planners to prioritize projects that provide the greatest overall benefits, considering both immediate hydrological needs and long-term urban sustainability goals (Saddiqi, Zhao, Cotterill, & Dereli, 2023).

In a suburban setting, such as the outskirts of Los Angeles, where sprawling development and increased impervious surfaces pose significant challenges to stormwater management, the framework can be applied to evaluate a network of bioswales and constructed wetlands designed to manage runoff and enhance groundwater recharge.M etrics related to groundwater recharge rates, biodiversity enhancement, and social equity are particularly relevant, as these projects manage stormwater and contribute to regional water security and ecological restoration. The framework's adaptability allows for a nuanced evaluation that considers the specific needs and characteristics of the suburban landscape, guiding the development of green infrastructure solutions that maximize both environmental and community benefits.

For a hypothetical scenario in an arid region, such as Phoenix, Arizona, where water scarcity and extreme heat are primary concerns, the framework could be applied to evaluate the effectiveness of xeriscaping (landscaping that reduces or eliminates the need for irrigation) and stormwater capture systems designed for water reuse. Metrics like water use efficiency, reductions in potable water demand, and resilience to extreme heat events are emphasized, reflecting the unique challenges of managing stormwater in an arid climate. The framework's comprehensive approach ensures that green infrastructure solutions are tailored to local conditions, providing the region with the most appropriate and sustainable outcomes.

### 4.3. Factors Influencing the Effectiveness of Green Infrastructure in Different Contexts

The effectiveness of green infrastructure is influenced by various factors that vary across different urban settings. These factors include local climate and weather patterns, land use and development density, soil types and permeability, and socio-economic conditions. For example, in regions with high rainfall and frequent storms, green infrastructure must be designed to handle large volumes of water and prevent flooding, while in arid regions, the focus is on maximizing water conservation and minimizing evaporation. Similarly, green infrastructure must be multifunctional and integrated into existing urban structures in densely populated cities with limited space. In contrast, in suburban or rural areas, there may be more flexibility to create larger, more naturalistic green spaces (Hansen, Olafsson, Van Der Jagt, Rall, & Pauleit, 2019).

Socio-economic conditions also play a critical role in determining the effectiveness of green infrastructure. In communities with limited financial resources, the upfront costs of implementing green infrastructure can be a significant barrier, even if the long-term benefits outweigh those costs. The framework's inclusion of economic metrics helps highlight the cost-effectiveness of green infrastructure solutions. It can support efforts to secure funding or incentives for projects in underserved areas. Additionally, social factors such as community engagement and public perception can influence the success of green infrastructure projects. Projects that involve community input and are designed to meet local needs are more likely to be accepted and maintained over the long term, enhancing their effectiveness (Miller & Montalto, 2019).

Another important consideration is the regulatory and policy context in which green infrastructure is implemented. Local regulations, zoning codes, and building standards can either facilitate or hinder the adoption of green infrastructure practices. The framework's adaptability allows it to be applied in different regulatory environments, providing a basis for advocating for policy changes that support more sustainable stormwater management practices (Ronchi, Arcidiacono, & Pogliani, 2020).

## 5. Conclusion and Future Directions

This paper has proposed a comprehensive theoretical framework for evaluating green infrastructure in urban stormwater management. The framework integrates environmental, economic, and social dimensions to provide a holistic assessment of green infrastructure's effectiveness across varied urban settings. By encompassing these three dimensions, the framework captures the multifaceted benefits of green infrastructure, from reducing stormwater runoff and enhancing water quality to promoting social equity and economic efficiency. Through a detailed review of existing literature, this paper identified gaps in current evaluation methods, such as the lack of a unified approach that considers all dimensions of sustainability. The proposed framework addresses these gaps by offering a more nuanced and inclusive tool for assessing the performance of green infrastructure projects.

The implications of this framework for urban planning and infrastructure projects are significant. As cities continue to grow and face increasing challenges from climate change, urban planners and policymakers must adopt more sustainable and resilient approaches to managing stormwater. The proposed framework provides a structured approach to evaluating green infrastructure that can inform decision-making and prioritize projects that deliver the greatest overall benefits. For example, in densely populated cities, the framework can guide the integration of green roofs, permeable pavements, and rain gardens into existing urban landscapes, maximizing multifunctionality and optimizing land use. In suburban and rural areas, where land availability is less constrained, the framework can help identify opportunities for larger-scale interventions like constructed wetlands and bioswales that enhance groundwater recharge and support biodiversity.

Furthermore, the framework's adaptability to different urban settings and climates ensures that it can be applied universally, providing a valuable tool for cities worldwide. Flood mitigation is a priority in arid regions, where water conservation is critical, or tropical climates. The framework allows for a tailored approach that considers local conditions and needs. This adaptability is crucial for developing green infrastructure solutions that are not only effective but also contextually appropriate, ensuring that they deliver maximum benefits in terms of stormwater management, environmental enhancement, and social well-being.

While the proposed framework offers a robust foundation for evaluating green infrastructure, there are several areas where future research is needed to refine and validate its components. First, empirical studies are needed to test the framework's criteria and metrics in real-world settings across various urban environments and climates. Such studies would provide valuable data on the effectiveness of different green infrastructure interventions and help refine the framework's metrics to ensure they accurately capture the diverse benefits of these systems. Additionally, research is needed to explore the social dimensions of green infrastructure more deeply, particularly regarding how different communities perceive and engage with these projects. Understanding the social factors that influence the success of green infrastructure can help design more inclusive and equitable interventions, ensuring that all urban residents benefit from sustainable stormwater management solutions. Moreover, future research should investigate the long-term performance of green infrastructure projects under changing climate conditions. As the frequency and intensity of extreme weather events increase, understanding how green infrastructure can be designed and maintained to remain effective over time is critical. This research could inform the development of adaptive management strategies that enhance the resilience of green infrastructure, ensuring it continues to provide essential services in the face of climate change.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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