INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 15, Issue 01, (2025) E-ISSN: 2222-6990

Unlocking the Potential of Green Infrastructure in Residential Areas: A Comprehensive Systematic Review

Nursah'aidah Md Sahak*, Mohd Yazid Mohd Yunos, Suhardi Maulan, Nor Atiah Ismail

Department of Landscape Architecture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

Coressponding Author Email: nursahaidah@gmail.com

To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v15-i1/24463 DOI:10.6007/IJARBSS/v15-i1/24463

Published Date: 27 January 2025

Abstract

Green infrastructure (GI) offers a sustainable solution to urban challenges in residential areas, providing benefits like effective stormwater management, climate mitigation, and improved well-being. This review follows PRISMA guidelines to analyse global case studies and research on GI, evaluating its potential, challenges, and opportunities in residential settings. Data were gathered from peer-reviewed articles and grey literature, focusing on ecosystem services, sustainability, and urban resilience. The review highlights GI's multifunctionality, showing benefits such as flood risk reduction, biodiversity enhancement, and urban cooling, while addressing implementation challenges. Global case studies, including Sponge City programs in China, SuDS in Newcastle, and vertical gardens in Singapore, illustrate diverse GI applications. A comprehensive approach involving public awareness, policy support, technical training, financial incentives, and stakeholder collaboration is key to overcoming barriers. In Malaysia, adopting frameworks like SuDS and eco-friendly solutions, such as rain gardens and green roofs, can enhance urban stormwater management and resilience. This study emphasizes equitable GI adoption, addressing environmental inequality, and fostering community engagement. Future research should assess GI benefits, understand demographic variations, and integrate GI with urban systems through cross-disciplinary collaboration. By bridging knowledge gaps and fostering partnerships, GI can create sustainable, resilient residential communities, supporting environmental conservation and quality of life for residents.

Keywords: Green Infrastructure, Residential Area, Environmental Benefits, Urban Development, Green Spaces, Sustainability, Neighbourhood Improvement, Urban Planning

Introduction

Background of Green Infrastructure

Green infrastructure (GI) is defined as a strategic approach that employs natural processes and systems to support urban development and land use planning while delivering multiple benefits to society, the economy, and the environment. According to a comprehensive entry in the Palgrave Encyclopedia of Urban and Regional Futures, GI utilizes nature and natural mechanisms for infrastructure development, emphasizing its multifunctional characteristics that provide various ecosystem services simultaneously. These benefits can be achieved both directly and indirectly through the implementation of GI initiatives (Osei et al., 2022). There are key characteristics of GI; nature-based solutions (Osei et al., 2022), multi-functionality (Ying et al., 2021), and integration with urban planning (Ying et al., 2021). GI incorporates both green (vegetation) and blue (water-related) elements, such as parks, green roofs, wetlands, and permeable surfaces, which are essential for sustainable drainage systems. This integration helps manage urban challenges like stormwater management and urban heat islands. The structural approach of GI allows it to produce multiple services, supporting biodiversity, improving air quality, and enhancing recreational opportunities for communities. This multifunctionality is crucial for addressing contemporary urban issues while promoting ecological health. GI emphasizes the importance of maintaining and restoring natural networks within urban settings. It advocates for a coordinated relationship between human activities and natural ecosystems, aiming to enhance resilience against climate change impacts.

GI provides extensive environmental, social, and economic benefits, making it a critical solution for addressing urban challenges such as climate change, pollution, and population growth. Environmentally, GI enhances stormwater management by utilizing permeable pavements, rain gardens, and green roofs to absorb and filter rainwater, reducing flooding risks and improving water quality (Aswani, 2023; Dipeolu & Ibem, 2020). It also supports ecosystem services such as air and water purification, biodiversity enhancement, and climate regulation, with urban forests and green roofs mitigating the urban heat island effect by providing shade and cooling (Ying et al., 2021; Wilo, 2024; EPA, 2024). Furthermore, GI fosters urban wildlife conservation by creating habitats in parks and community gardens, promoting ecological balance and biodiversity (Aswani, 2023). Socially, GI improves public health and well-being by offering access to green spaces that enhance mental health, encourage physical activity, and foster community interaction, while also improving resilience against climate-related hazards such as heatwaves and flooding (Wilo, 2024; Ying et al., 2021; Herath & Bai, 2024; Sang & Pan, 2024). Economically, GI is cost-effective, reducing infrastructure expenses for stormwater management and energy consumption, with green roofs lowering utility costs and boosting property values in areas with well-maintained green spaces (Sang & Pan, 2024; EPA, 2024; Ying et al., 2021). Additionally, GI contributes to local economies by creating jobs in landscaping and environmental management, and reducing healthcare costs by promoting healthier lifestyles and improving air quality (Aswani, 2023; EPA, 2024). By integrating natural systems into urban planning, GI ensures ecological health, social equity, and economic viability, making it essential for creating sustainable, resilient, and liveable urban environments as cities continue to expand (Aswani, 2023; Ying et al., 2021; Wilo, 2024; Sang & Pan, 2024; Herath & Bai, 2024).

The interchange between urbanization and stormwater management has become increasingly critical as cities worldwide face heightened environmental challenges driven by climate change, urban development, and technological advancements. Climate change is altering rainfall patterns, causing more frequent and intense storms that overwhelm municipal systems designed using historical data, leading to heightened flood risks and water quality issues from increased pollutant loads in runoff (Hathaway et al., 2024; EPA, 2024). These impacts are regionally variable, with some areas, such as the U.S. Northeast, experiencing intensified precipitation, while others, like the desert Southwest, face prolonged droughts, necessitating locally tailored management strategies (Hathaway et al., 2024). Urbanization exacerbates these challenges by increasing impervious surfaces, such as roads and buildings, which intensify runoff and pollution, while regulatory frameworks like the EPA's National Pollutant Discharge Elimination System (NPDES) demand stricter stormwater management, often transferring responsibilities to private developers to implement onsite retention strategies (Coppes, 2021; EPA, 2024). Technological innovations, including geospatial tools and AI-based data extraction, are transforming stormwater management through improved flood modelling and resilience planning, while nature-based solutions like bioretention systems and green roofs are increasingly integrated into urban designs to manage runoff, enhance biodiversity, and improve air quality (Hathaway et al., 2024; EPA, 2024). Moving forward, adaptive management strategies that modify stormwater system designs based on recent climatic patterns, rather than historical norms, will be critical for resilience, alongside community engagement and education to foster sustainable practices and encourage local involvement in stormwater initiatives (Hathaway et al., 2024; Coppes, 2021; EPA, 2024). A multifaceted approach that combines innovation, regulatory compliance, and public participation will be essential to address these challenges and ensure sustainable water management in growing urban areas.

This study is motivated by the pressing need to address the limitations and challenges of urban stormwater management in residential areas, particularly in rapidly urbanizing regions like Kuala Lumpur. Despite the introduction of the Malaysia Urban Stormwater Management Manual (MSMA), the practical implementation of its guidelines remains inconsistent, leading to issues such as ineffective drainage systems, urban flooding, and environmental degradation. The key contribution of this research lies in its development of an enhanced framework to improve the effectiveness of MSMA guidelines. By integrating document analysis with expert insights, this study provides a comprehensive assessment of MSMA's performance, highlights governance and infrastructure challenges, and offers actionable recommendations for sustainable stormwater management. The findings are expected to benefit policymakers, urban planners, and stakeholders in advancing resilient and sustainable practices in urban areas.

Previous Literature Review

Recent studies and reports have identified critical knowledge gaps in the implementation and optimization of GI in residential areas, highlighting the need for technical expertise, robust data, effective governance, and financial strategies. A significant lack of localized hydrological data further hampers efforts, as much of the current knowledge on blue-green infrastructure (BGI) stems from wealthier nations, neglecting the unique conditions of regions like Southeast Asia (Hamel & Tan, 2022). The absence of standardized performance metrics and data collection protocols complicates the evaluation of GI systems, limiting insights into their long-term effectiveness, maintenance needs, and outcomes across social, economic, and ecological dimensions (Khalili et al., 2024; Parker and Zingoni de Baro, 2019; Zamiri & Esmaeili, 2024). Governance challenges also persist, with inadequate stakeholder participation and regulatory frameworks that fail to support innovative GI solutions or address local needs (Loveday et al., 2022; Zuniga-Teran et al., 2019). Financial barriers, including insufficient funding and a lack of comprehensive cost-benefit analyses, further constrain GI adoption, particularly in low-income areas (Zuniga-Teran et al., 2019). Moreover, the integration of climate resilience strategies into GI design is often insufficient, with projects failing to account for future climate scenarios (Zuniga-Teran et al., 2019). Addressing these gaps will require collaborative efforts from municipalities, researchers, and communities to enhance technical knowledge, improve data collection, establish inclusive governance, and develop innovative funding mechanisms, ultimately enabling GI to achieve its environmental and social potential.

The purpose of this systematic study is to provide a comprehensive review of the potential, challenges, and opportunities associated with the implementation of GI in residential areas. This review aims to identify critical knowledge gaps, highlight best practices, and explore strategies to optimize GI's effectiveness in enhancing urban sustainability and resilience. By synthesizing existing literature, this study seeks to offer valuable insights into how GI can address environmental, social, and economic needs within residential settings while overcoming barriers related to governance, technical integration, data limitations, and financial constraints.

Method

When defining GI for stormwater and flood management, we adopted a broad concept of GI as natural spaces that provide flood protection and improve water quality in urban areas (Chenoweth et al., 2018; U.S. EPA, 2024). Our scope encompassed GI at the neighbourhood and site scale within cities, considering it as an infrastructure utilizing vegetation, soils, and other elements to restore natural processes for water management and healthier urban environments (U.S. EPA, 2024). Our review focuses on residential GI and its significance for stormwater management, with examples like rain gardens, green roofs, bioswales, and more (Kloos and Renaud, 2016).

Search Strategy

To obtain relevant knowledge, we conducted a systematic literature search using interdisciplinary research databases (Science Direct, Pubmed, Scopus & Springer) to identify pertinent articles. We used specific search terms related to GI in residential areas, benefits of GI in residential areas, challenges of GI in residential areas, and related topics. The search period covered articles published from January 1st, 2017, to May 31st, 2024, to capture the latest literature as Table 1 below.

Table 1
Database Search Strategy

Electronic database	Search terms
Science Direct search	'Green infrastructure in residential area or housing area' OR 'Benefit of green infrastructure in residential or housing area' OR 'Challenges and constraints of green infrastructure in residential or housing area'
Pubmed search	Green infrastructure, green infrastructure in residential areas, benefit or opportunities in green infrastructure, challenges and constraints of green infrastructure
Scopus search	Green infrastructure AND residential area AND housing area OR Benefit AND green infrastructure AND in residential AND housing area OR Challenges AND constraints AND green infrastructure AND in residential AND housing area
Springer search	Green infrastructure in residential area or housing area, Benefit of green infrastructure in residential or housing area, Challenges and constraints of green infrastructure in residential or housing area

Inclusion and Exclusion Criteria

In our initial search, we considered any GI or greenspace projects explicitly designed for stormwater or flood management in residential areas. We retained studies that met our eligibility criteria even if they were not exclusively in urban settings. We excluded commentaries, editorials, blog posts, publicity materials, or news and magazine articles to maintain scientific objectivity. After removing duplicates, we screened citations based on titles and abstracts. Our review focused on open-access articles in the English language. We included studies that applied GI in residential areas but excluded studies conducted in farm areas, industrial or institutional buildings, or multiple articles on the same topic by the same author.

Study Selection

Records that met the exclusion criteria were removed after titles and abstracts were scanned. There was no specific geographic limitation as long as the GI adaptation was in residential areas. Studies focusing on the value and use of GI were included. Full-text screening was conducted with the exclusion criteria, which consisted of studies using quantitative research methods, studies not specific to residential areas, and studies lacking design processes, guidelines, or strategies.

From the initial pool of 2,531 records, 190 titles were identified as relevant. An updated search utilizing the snowball method yielded an additional 35 studies. Following the application of exclusion criteria to 105 full-text studies, a final selection of 80 articles was made (Figure 1).

Data Extraction and Quality Assessment

Data extraction was performed using a designed extraction sheet, including information on country, type of GI, research tools, research methods, GI application stages, and focuses. A second independent researcher cross-checked the extracted data. A quality assessment was conducted using the Critical Appraisal Skills Programme (CASP) tool, and reviewers extracted and evaluated data from each study. Discrepancies were resolved through discussions.

Data Synthesis

A thematic analysis was carried out on the selected studies, which were classified and summarized in three different perspectives of GI in residential area: (1) GI in residential area; (2) the benefit and challenges of Gi in residential area; (3) roles of urban planning and policy. The results related to each theme are presented in the following sections.

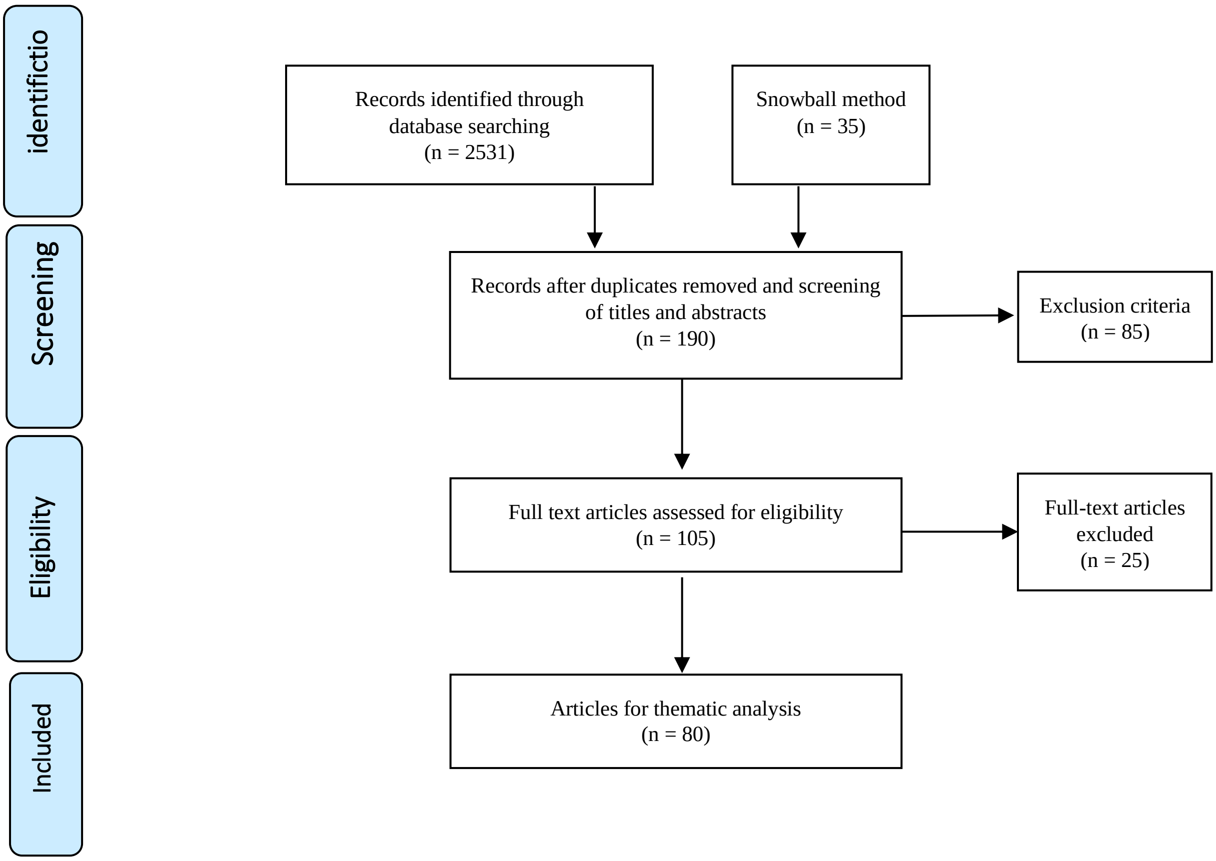

Fig. 1 The literature review process (PRISMA flow chart)

Overview of GI Principles

GI serves as a critical strategy in urban planning, offering a multifaceted approach to addressing pressing challenges such as stormwater management, biodiversity loss, and urban heat islands. By integrating environmental, social, and economic sustainability pillars, GI enhances ecosystem services while promoting resilient urban environments. One of its core principles, multifunctionality, enables GI to perform several roles simultaneously. For instance, green roofs mitigate stormwater runoff, reduce urban temperatures, and provide habitats for wildlife, thus addressing both ecological and urban challenges (Wang et al., 2024;

Isola et al., 2024). The principle of connectivity emphasizes the creation of ecological networks—comprising parks, urban forests, and other green spaces—that facilitate species movement and strengthen biodiversity. This connectivity not only sustains urban ecosystems but also enhances resilience to environmental changes (Wang et al., 2024; Semeraro et al., 2017).

The adaptive management of GI is another vital principle, requiring iterative and participatory approaches that allow green infrastructure to evolve with changing urban conditions and stakeholder needs (Wang et al., 2024). This ensures that GI systems remain flexible and effective in maximizing their ecological and social benefits over time. In terms of ecosystem service provisioning, GI contributes significantly to urban stormwater management by enhancing natural infiltration and reducing runoff, thereby mitigating flooding risks (Isola et al., 2024). It also supports urban biodiversity by creating diverse habitats for flora and fauna, which are essential for maintaining ecological balance (Wang et al., 2024; Semeraro et al., 2017). Additionally, vegetated areas within GI systems play a crucial role in urban cooling through evapotranspiration and shading, improving thermal comfort and reducing the urban heat island effect (Wang et al., 2024; Isola et al., 2024).

The social and economic benefits of GI further underscore its importance. Economically, GI reduces infrastructure costs by minimizing the need for traditional grey infrastructure, such as storm sewers, and mitigates maintenance expenses related to flood damages (Ashinze et al., 2024). Socially, it enhances public health by providing accessible green spaces that promote physical activity, mental well-being, and social interaction (Monteiro et al., 2022). Furthermore, GI fosters community cohesion by creating shared spaces for engagement and recreational activities while addressing disparities by ensuring equitable access to these spaces (Monteiro et al., 2022; Mensah, 2019). Through its multifunctionality, connectivity, adaptive management, and contributions to ecosystem services, GI exemplifies a sustainable and holistic approach to urban development. By integrating natural systems with built environments, GI not only addresses immediate urban challenges but also fosters long-term resilience to climate change and urbanization. A collaborative effort involving policymakers, urban planners, and communities is vital to fully harness the potential of GI in enhancing ecological integrity, social well-being, and economic viability (Mell & Clement, 2019; Ying et al., 2021).

GI aligns seamlessly with global sustainability frameworks, including the United Nations Sustainable Development Goals (SDGs), climate action initiatives, and local urban development policies. By addressing environmental, social, and economic dimensions, GI plays a pivotal role in achieving sustainable urban development. GI contributes significantly to SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) by revitalizing underutilized urban spaces, enhancing ecological diversity, and fostering socio-economic revitalization (Mell, 2022). It also strengthens urban ecosystem services, which are essential for achieving multiple SDGs, emphasizing the need to integrate GI into urban planning to maximize its contribution to sustainable development (Hawken et al., 2021). Furthermore, GI aligns with global climate action goals by promoting nature-based solutions that mitigate climate impacts, reduce urban vulnerability, and enhance resilience. Initiatives such as integrating green and blue infrastructure not only address climate challenges but also promote human health and ecological well-being (Pinto et al., 2023; Almulhim et al., 2024).

On the local level, GI aligns with urban development policies by addressing specific environmental challenges while harmonizing practices across regions. This integration ensures that local actions resonate with global sustainability goals. Research highlights the necessity of embedding GI into policy frameworks to enhance ecosystem services, strengthen urban resilience, and foster sustainable development at multiple scales (Mell & Clement, 2019; Sokolova et al., 2024). By bridging global frameworks with localized strategies, GI represents a vital tool for creating resilient and sustainable urban environments, demonstrating its capacity to adapt to diverse socio-ecological contexts and to meet the broader objectives of global sustainability agendas.

Role of Urban Planning and Policy

Cities worldwide employ diverse strategies to develop their GI, considering cultural, physical, and ecological aspects (Gradinaru and Hersperger, 2019). Effective GI planning involves anticipating future challenges and establishing long-term goals through strategic planning that spans decades (Albrechts et al., 2017). GI's significance in social, economic, and ecological contexts highlights its central role in urban planning. Integrating GI effectively requires reforming existing planning laws and policies across administrative levels, emphasizing GI's role in urban resilience and sustainability (Pamukcu-Albers et al., 2021). Reforms for GI integration should be adaptable to socio-political and geographical contexts. Urban governance, driven by administrators and public decision-makers, can influence spatial transformations by establishing rules, incentives, and constraints (Pamukcu-Albers et al., 2021). Making GI inclusion mandatory in spatial planning at various levels can mainstream GI and enhance its utilization in planning processes.

Building GI requires multi-sectoral and stakeholder collaboration. Digital technologies facilitate information exchange among municipal departments, while participatory decision-making enhances urban governance (Pamukcu-Albers et al., 2021). Quality planning and management of public GI demand well-trained staff, effective measures, and local actor involvement (Ugolini et al., 2020). Participatory approaches, engaging stakeholders and the public, are essential for evaluating cultural and social values, empowering citizens, and fostering community and belonging (Rall et al., 2019). Collaboration and participation are indispensable in sustainability science and landscape and urban planning (Opdam et al., 2018; Milovanovic et al., 2020; Cumming and Epstein 2020; Opdam, 2020).

Types of GI in Residential Areas

GI integrates natural elements to address environmental challenges (Derkzen et al., 2017). Examples include rain gardens for stormwater control and urban trees for heat reduction (Drescher and Sinasac, 2021), offering co-benefits for people (Bratman et al., 2019). Many global cities plan to expand GI to enhance climate resilience, urban liveability, and human well-being (Derkzen et al., 2017; Matsler et al., 2021). This extends to green pathways alongside roads and railways, with water features termed 'blue infrastructure.'

A vital aspect of GI's integration into sustainable cities involves encouraging residents to implement GI in their private residential outdoor spaces. Private residential spaces encompass areas around homes on personal property, including yards, porches, driveways, decks, and patios (Corley et al., 2021). Residential GI installation is essential for establishing extensive and evenly distributed GI networks (Conway et al., 2020).

Common GI elements found in residential areas

Numerous studies support the implementation of sustainable stormwater practices like green roofs, rain gardens, bioretention systems, pervious pavements, and rainwater harvesting (Shafique & Kim, 2017; Campisano et al., 2017). Particularly in high-rise buildings, roof areas are crucial for stormwater management, comprising up to 50% of the total area (Shafique & Kim, 2017). Green roofs (Figure 2), as vegetated Sewer System Management Plans (SSMP), address impermeable areas, especially in densely urban high-rise buildings (Maqsoom et al., 2021; Berland et al., 2017; Shafique and Kim, 2017). Ground areas, occupied by complex infrastructure, allow runoff storage and natural infiltration through the soil (Shafique & Kim, 2017).

Bioretention systems consist of filter media layers, an overflow weir, various vegetation, and an optional underdrain, while rain gardens share a similar concept but have different design requirements, with rain gardens not requiring the multiple filter media layers needed for bioretention systems (Kordana & Slys, 2020). Both practices as shown in Figure 3, collect and store runoff, allowing it to be evaporated through vegetation. Soil and vegetation aid in pollutant and sediment treatment for water quality (Kordana & Slys, 2020). Permeable pavements (Figure 4) facilitate the infiltration of stormwater into the ground, which helps to mimic pre-urban hydrological conditions. This infiltration reduces both the peak flow and volume of urban runoff, thereby alleviating flooding risks in cities. Studies show that permeable pavements can effectively reduce stormwater discharges by 25% to 100%, depending on design and site conditions (Razzaghmanesh & Borst, 2019).

Rainwater harvesting (RWH) technology includes various types of tanks designed to collect and store rainwater, catering to needs ranging from residential homes to multi-story buildings. Above-ground tanks, such as small barrels made of plastic or metal, are commonly used in residential settings for irrigation and runoff control, with capacities ranging from a few hundred litres to several cubic meters, making them ideal for single-household applications during dry seasons (Campisano et al., 2017). Below-ground tanks, like concrete cisterns, are larger and better suited for multi-story buildings, efficiently supporting high-demand applications by maintaining water temperature and reducing evaporation losses (Campisano et al., 2017). Hybrid systems combine above-ground and below-ground storage, offering flexibility in usage and optimizing space utilization in urban areas where building footprints are limited (Raimondi et al., 2023). The illustration in Figure 5 serves as an exemplar of on-surface rainwater harvesting.

Figure 2: Green Roofs and Green Walls. Green roofs involve planting vegetation on rooftops, while green walls are vertical gardens attached to buildings. These features offer insulation, reducing heating and cooling costs, improve air quality, and provide aesthetic value to residential buildings.

Source: lushome.com

Figure 3: Rain Gardens and Bioretention. Rain gardens are landscaped depressions that capture and treat stormwater runoff, allowing it to infiltrate the soil naturally. Bioswales provides efficient treatment of stormwater through fine filtration, extended detention and some biological uptake. These features help reduce stormwater runoff, improve water quality, and prevent flooding.

Source: https://blog.landscapeprofessionals.org/

Figure 4: Permeable Pavements. Permeable pavements are surfaces that allow water to pass through them, reducing runoff and allowing water to infiltrate into the ground. They aid in stormwater management, prevent surface water pooling, and contribute to groundwater recharge.

Source: https://www.milorganite.com/

Figure 5: Rainwater Harvesting Systems. Rainwater harvesting systems collect and store rainwater for later use in residential properties. This practice conserves water and reduces the demand on municipal water supply. The figure shows an example of rainwater harvesting on the ground.

Source: https://vaswcd.org/

Centralized and Decentralized Systems of GI

GI incorporates a range of strategies to manage stormwater, enhance water quality, and support urban ecosystems. The decision between centralized and decentralized systems is pivotal for urban planners and environmental managers, as each approach offers distinct advantages and challenges. Centralized systems typically involve large-scale treatment plants that process wastewater or stormwater at a single location, leveraging economies of scale to provide cost-effectiveness in densely populated areas (Saadatinavaz et al., 2024). These systems are fully funded by public sources, allowing municipalities to maintain comprehensive control over environmental objectives, including pollutant removal and flood mitigation (Romeiko, 2020). However, centralized systems are often energy-intensive, contributing significantly to greenhouse gas emissions, which raises sustainability concerns, particularly in the context of climate change (Romeiko, 2020).

In contrast, decentralized systems function on a smaller scale, addressing wastewater or stormwater management near the source, such as at individual properties or within small communities. This localized approach enables tailored management practices that adapt to specific environmental conditions (Romeiko, 2020). Examples of decentralized infrastructure include green roofs, rain gardens, permeable pavements, and on-site treatment systems like septic tanks, which can be integrated into existing landscapes with minimal disruption (Meierdiercks & McCloskey, 2022). These systems generally involve lower initial capital costs and reduced energy consumption due to their smaller scale. Nonetheless, they demand ongoing maintenance and public education to ensure operational effectiveness (Słyś & Stec, 2020), and variability in treatment quality can pose risks to human health and the environment if improperly managed (Romeiko, 2020). Notably, decentralized systems may exhibit lower life cycle health impacts compared to centralized systems, with reduced risks of microbial contamination and other health hazards (Romeiko, 2020; Saadatinavaz et al., 2024).

Performance metrics between centralized and decentralized systems often differ based on local conditions. For instance, decentralized GI practices, such as infiltration-based systems, are highly effective in reducing flood volumes by managing stormwater at the source. In contrast, centralized wetlands may excel in slowing peak discharges but might be less effective in reducing overall flood volumes at the catchment scale (Meierdiercks & McCloskey, 2022; Saadatinavaz et al., 2024). Regarding water quality improvement, centralized systems offer significant pollutant removal through large-scale treatment processes, while decentralized systems contribute localized benefits by enhancing water quality in specific areas (Meierdiercks & McCloskey, 2022; Saadatinavaz et al., 2024).

Ultimately, the selection between centralized and decentralized green infrastructure depends on factors such as population density, regulatory requirements, environmental goals, and economic considerations. A hybrid approach that combines both systems often represent the most resilient solution, capitalizing on the strengths of each while addressing their respective limitations. Centralized systems provide efficiency for large populations, while decentralized approaches offer flexibility and localized benefits, enhancing community resilience to flooding and improving environmental health outcomes.

Benefits of GI

GI is recognized as a means to promote sustainability and climate resilience (Kim & Song, 2019), efficiently managing ecosystem services' advantages (Gren & Andersson, 2018). GI's multifunctionality enhances urban ecosystems and aligns with semi-natural areas in cities, underscoring its potential to oversee diverse ecological, social, and economic services (Artmann et al., 2017). Urban allotment gardens, part of GI, boost household income through agriculture (Tappert et al., 2018), benefiting biodiversity and environmental functions through green spaces (Kim & Song, 2019). Biological structures akin to ecosystems deliver benefits to people (Kim & Song 2019). Urban areas face climate-related risks and threats, emphasizing the role of green and blue spaces within green and blue infrastructure (Sayli & Berjis, 2021). The links between urban green spaces and human well-being contribute to urban vitality and active lifestyles (Jabbar et al., 2022).

Combining GI components effectively reduces runoff volume (Zhang et al., 2021), while permeable surfaces and green roofs are essential for future geospatial strategies to ensure resilience (Twohig et al., 2022). Residential rainwater harvesting in densely populated areas plays a significant role in stormwater management when coupled with widespread participation and adequate tank storage (Deitch & Feirer, 2019). Rain gardens, popular in the United States, improve stormwater runoff quality (Morash et al., 2019). A study by Garbanzos & Maniquiz-Redillas (2022) demonstrates that combining bioretention, infiltration trenches, and permeable pavement maximizes infiltration and groundwater recharge, highlighting the substantial impact of Low Impact Development (LID) practices. Further details of multifunctionality of GI and types of community benefits can be acquired from Table 2.

Table 2
Multifunctionality of GI and types of community benefits

Functionality	Type of benefit	Description
Economic	Enhance economic capacity	- Local economic development with community benefits and promotion of vital urban centers (Tappert et al., 2018) - Improved marketability (Ziogou, 2018) - Increased retail sales (Jia & Zhang, 2021; Ziogou, 2018) - Increased property values and tax revenue (Ziogou, 2018) - Reduced costs associated with infrastructure, development, flooding, water treatment, and healthcare (Ziogou, 2018; Ran & Tang, 2018) - Reduced use of energy (for cooling), salt (for icy roads), and water (Anguelovski et al., 2018) - Urban agriculture/sustainable food production (Langemeyer et al., 2020; Anguelovski et al., 2018) - Green job creation (Zwierzchowska et al., 2019)
Sociocultural	Educational opportunities	- Increased recreational opportunities and interactions with nature (Langemeyer et al, 2020)
	Increase in social capital	- Community development and stronger community cohesion (Truong et al., 2022; Langemeyer et al., 2020; Zwierzchowska et al., 2019) - Opportunities for youth to spend time in public spaces (Wan et al., 2018) - More social gathering spaces (Hendricks et al., 2018) - Cultural expression (Hendricks et al., 2018) - Increased physical/mental health (Klein et al., 2022; Jabbar et al.,2022; Zwierzchowska et al., 2019)
	Landscape aesthetics	- Improved aesthetics (Wan et al., 2018)
Ecological	Basis of sustainable development	- Regulatory compliance credits - A high-quality environment to attract and retain a competent workforce (Gren & Andersson, 2018) - Links between towns and the countryside (Gren & Andersson, 2018)
	Runoff control	- Flood control/prevention, storm surge protection, and accommodation of natural hazards (Deitch & Feirer, 2019) - Better management of stormwater runoff (Abera et al., 2021; Chen et al., 2021; Zhang et al., 2021; Langemeyer et al., 2020) - Maintenance of predevelopment runoff volumes and discharge rates (Garbanzos & Maniquiz-Redillas, 2022)
	Enhanced environmental soundness	- Preservation of terrestrial and aquatic habitats (Anguelovski et al., 2018; Xiao, 2018; Ziogou, 2018) - Improved air quality and less carbon dioxide in the atmosphere (Ziogou, 2018) - Biodiversity protection and pollination (Langemeyer et al., 2020; Anguelovski et al., 2018; Xiao, 2018; Ziogou, 2018) - Protection to enhance geologically important sites, such as nature preserves and heritage sites (Anguelovski et al., 2018; Xiao, 2018; Ziogou, 2018) - A reduced of ecological footprint (Anguelovski et al., 2018; Xiao, 2018; Ziogou, 2018)
	Climate change adaptation	- Reduced urban heat islands and ambient temperatures (Langemeyer et al., 2020; Ran & Tang, 2018) - Improve thermal environment on the rooftop (Knaus & Haase, 2020) - Resilient infrastructure and climate change adaptation/mitigation (Zwierzchowska et al. 2019)

Sources: Kim & Song (2019)

Case Study and Successful Examples

The following tables (Table 3, Table 4, Table 5) present a summary of case studies from various cities worldwide that have successfully implemented GI solutions to address urban water management challenges. These case studies highlight the strategies adopted, key focus areas, and outcomes related to flood risk reduction, water quality improvement, and climate resilience. Additionally, the table identifies key lessons learned from these experiences, providing valuable insights for urban planners and policymakers looking to integrate nature-based solutions into their own cities.

Table 3
Case Studies on the Integration of GI in Urban Water Management in Newcastle (UK), Rotterdam (Netherlands), Portland (USA), and Ningbo (China)

City	*Newcastle (UK)*
Core Strategy	Emphasis on the "four pillars of SuDS"—water quantity, quality, amenity, and biodiversity.
Focus Area	- Flood risk reduction - Water quality improvement - Urban green spaces for social and biodiversity benefits
Perception & Outcomes	Over 90% of residents value BGI's multifunctionality, showing strong public understanding and acceptance.
Key Lessons	Adopt a balanced framework like SuDS to integrate water, social, and ecological goals.
City	*Rotterdam (Netherlands)*
Core Strategy	Climate resilience through "Waterplan" (Rotterdam Weather-Wise), integrating blue corridors and green spaces.
Focus Area	- Enhancing urban water and air quality - Promoting biodiversity - Improving quality of life via multifunctional spaces
Perception & Outcomes	BGI is seen as a tool for climate resilience, enhancing city liveability, and addressing broader social challenges.
Key Lessons	Focus on climate adaptation by blending urban water management with public space transformation.
City	*Portland (USA)*
Core Strategy	Uses BGI to achieve Climate Action Plan goals, prioritizing natural systems over traditional infrastructure.
Focus Area	- Water quality improvement - Flood risk management - Carbon sequestration through urban greenery
Perception & Outcomes	Residents unanimously prioritize BGI for ecological health and resilience, driven by strong environmental policies.
Key Lessons	Combine carbon sequestration with water management to align with climate goals.
City	*Ningbo (China)*
Core Strategy	Implements Sponge City Programs (SCP) to manage extreme rainfall and integrate nature into urban planning.
Focus Area	- Flood risk management - Natural environment enhancement - Increased blue and green spaces
Perception & Outcomes	BGI is seen as vital for addressing water challenges while enhancing urban living experiences.
Key Lessons	Leverage nature-based solutions like SCP for extreme weather and urban resilience.

Sources: O'Donnell et al., 2021

Table 4
Case Studies on the Integration of GI in Urban Water Management in Shanghai (China)

City	*Shanghai (China)*
Core Strategy	Sponge City project integrates eco-friendly methods like rain gardens, permeable pavements, and green roofs, supported by government and stakeholders.
Focus Area	- Flood risk mitigation - Groundwater recharge - Stormwater capture through over 200 pilot projects
Perception & Outcomes	Success evident in urban runoff control, improved water quality, and urban resilience (e.g., 30 pilot cities passed evaluations).
Key Lessons	Use coordinated stakeholder collaboration and eco-friendly solutions for large-scale urban water challenges.

Sources: Yin et al., 2022

Table 5
Case Studies on the Integration of GI in Urban Water Management in New York City (USA), Copenhagen (Denmark), and Singapore

City	*New York City (USA)*
Core Strategy	Extensive use of green roofs and rain gardens.
Focus Area	- Stormwater runoff reduction - Water quality improvement
Perception & Outcomes	Green roofs reduce runoff by up to 65%, alleviating drainage system pressure; rain gardens filter pollutants.
Key Lessons	Integrate rain gardens and green roofs to address urban drainage and water quality challenges.
City	*Copenhagen (Denmark)*
Core Strategy	Emphasis on integrated planning and community engagement for green infrastructure.
Focus Area	- Flood risk reduction - Environmental sustainability - Community resilience
Perception & Outcomes	Rain gardens have reduced flooding risks during heavy rainfall, enhancing sustainability and resilience.
Key Lessons	Foster community engagement and integrated planning for sustainable urban water solutions.
City	*Singapore*
Core Strategy	Strong government leadership promoting green roofs, vertical gardens, and sponge city initiatives.
Focus Area	- Stormwater management - Urban biodiversity improvement - Urban aesthetics
Perception & Outcomes	Known as the "City in a Garden," GI improves ecological health, stormwater management, and aesthetics.
Key Lessons	Promote government-led initiatives integrating green infrastructure into urban landscapes.

Sources: Soni et al., 2024

Challenges and Limitations of GI

GI offers significant benefits for urban areas by addressing climate change, enhancing resilience, and fostering sustainability. However, its implementation is hindered by multifaceted challenges across technical, policy, financial, and social dimensions. From a technical perspective, GI projects often lack standardization, creating inefficiencies in integration with existing urban frameworks and complications in maintenance, particularly in areas experiencing frequent rainfall (Zuniga-Teran et al., 2019). Policy-related challenges include fragmented governance structures and short political cycles, which impede long-term planning and prioritization of GI over conventional infrastructure. Furthermore, the absence of clear regulatory frameworks complicates the distribution of responsibilities for long-term maintenance and the equitable sharing of benefits, while many authorities lack mandates to adopt GI as a preferred alternative (Zuniga-Teran et al., 2020). Financial barriers are significant, as GI projects typically require higher upfront costs compared to traditional infrastructure, coupled with long payback periods that discourage investment. This financial viability gap is further widened by market uncertainties, inadequate financing models, and limited public-private partnerships, despite the potential for risk-sharing and resource mobilization through such collaborations (Nesshöver et al., 2017; Toxopeus & Polzin, 2021; Dai & Solangi, 2023).

Socially, GI implementation faces resistance due to limited public awareness and acceptance. Issues such as "green gentrification," where increased property values displace residents, and inequitable planning processes that exclude marginalized groups, exacerbate social inequalities (Zuniga-Teran et al., 2019; Djenontin & Meadow, 2018). Public acceptance is also tied to trust in political institutions, awareness of GI benefits, and socio-cultural considerations. Additionally, municipalities often lack the necessary expertise to plan, implement, and maintain GI, including skills in participatory and collaborative planning, which are critical for aligning diverse stakeholder interests (Bozovic et al., 2017). These challenges highlight the need for systematic, comprehensive, and collaborative approaches that address technical, governance, financial, and social dimensions. The successful integration of GI into urban planning requires innovative financing mechanisms, robust regulatory frameworks, and inclusive planning processes that ensure equitable distribution of benefits. By fostering collaboration among technical experts, policymakers, financial institutions, and communities, cities can overcome these barriers and unlock the full potential of green infrastructure in building sustainable, resilient urban environments (Zuniga-Teran et al., 2020; Toxopeus & Polzin, 2021; Nesshöver et al., 2017).

Summary of Findings

GI in residential areas offers multiple benefits, including effective stormwater management, climate mitigation, and improved resident well-being. Integrating GI into urban planning creates sustainable, resilient, and liveable communities, enhancing residents' quality of life and supporting environmental conservation. Case studies illustrate the effectiveness of GI in residential settings, positively impacting the environment, well-being, and overall urban sustainability. To overcome challenges, a comprehensive approach involving public awareness campaigns, policy support, technical training, financial incentives, and stakeholder collaboration is essential. Policymakers, urban planners, and environmental organizations have crucial roles in addressing these barriers, facilitating GI integration in residential areas. Coordination of efforts to raise awareness, provide technical expertise, and secure funding is pivotal for sustainable and resilient urban development. Continuous policy assessment and collaborative engagement between government, private sector, and communities are key to successful GI implementation and sustainable urban development.

Comparative Insights

The reviewed case studies reveal shared benefits of BGI, with stormwater management, flood risk reduction, and water quality improvement emerging as universally prioritized objectives. Secondary benefits, such as biodiversity enhancement, community engagement, and climate resilience, further highlight BGI's multifunctionality. Despite these commonalities, each city employs context-specific approaches. Newcastle emphasizes compliance with SuDS guidelines to achieve balanced social, environmental, and economic goals. Rotterdam integrates public space transformation with climate resilience strategies, while Portland combines flood management with carbon sequestration to address climate change. In Ningbo and Shanghai, large-scale Sponge City pilot programs exemplify nature-based solutions to urban resilience, driven by strong government support and stakeholder collaboration. Meanwhile, New York and Copenhagen leverage rain gardens and green roofs to mitigate drainage challenges and improve urban liveability. Singapore’s leadership in green roofs and vertical gardens illustrates how government-led initiatives can simultaneously enhance biodiversity, stormwater management, and urban aesthetics.

Applications for Malaysia

Malaysia can adopt these global lessons to enhance urban stormwater management and resilience. First, implementing multifunctional frameworks, such as SuDS and Sponge City concepts, can balance water management objectives with broader environmental and social goals. Second, eco-friendly methods like rain gardens, permeable pavements, and green roofs should be prioritized to manage urban stormwater effectively while promoting sustainability. Third, leveraging strong government leadership and collaboration with local stakeholders can ensure the seamless integration of green infrastructure into national and local urban planning strategies. Lastly, fostering community engagement and participation will strengthen public understanding and support for sustainable urban water solutions, ensuring long-term success.

Implications for Practices

This research has significant implications for GI management, especially in community initiatives aimed at promoting GI adoption in residential private areas. Local initiatives enhancing awareness and engagement with GI can be valuable, focusing on specific outdoor space uses and maintenance experiences. Experimental evaluations of message effectiveness in GI initiatives are necessary to guide program implementation. Community outreach efforts should provide residents with direct experiences involving GI features in public or private settings, impacting residential adoption likelihood. Differentiate government and non-governmental initiatives in future research to understand varying outreach strategies and resident perceptions.

Analysing how GI programs contribute to environmental inequality is crucial. Uneven distribution of GI features, particularly in disadvantaged urban areas, may exacerbate inequality, for example, by increasing housing prices. Address social barriers to GI adoption, as outreach programs tend to concentrate in high-income neighbourhoods, potentially worsening disparities. Future research should consider residents' perceptions of environmental equity in relation to GI behaviours.

Future Research and Knowledge Gaps

Future research on GI in residential areas should address residents' perceptions of environmental equity in relation to GI behaviours, critical knowledge gaps and emerging challenges to enhance sustainable urban planning. Priority areas include developing precise methods to assess the full range of GI benefits, exploring strategies for community engagement and equitable access, understanding demographic variations in GI experiences, and examining the role of policy and governance. Cross-disciplinary collaborations are essential to comprehensively address complex GI challenges and integrate GI with other urban systems.

Conclusion

The key principles behind green infrastructure in residential settings are to promote environmental sustainability, enhance urban resilience, improve the health and well-being of residents, and create attractive and vibrant neighbourhoods. Green infrastructure fosters a harmonious relationship between nature and urban living, contributing to more sustainable and inclusive residential developments. These types of green infrastructure in residential areas contribute to a range of benefits, including improved stormwater management, enhanced air quality, increased biodiversity, reduced urban heat island effects, and enhanced community well-being. Integrating green infrastructure into residential developments creates more sustainable and resilient neighbourhoods that promote the health and happiness of residents. In summary, green infrastructure in residential areas offers multiple benefits, ranging from practical stormwater management and climate mitigation to the improvement of residents' health and well-being. By integrating green infrastructure into urban planning and development, cities can create more sustainable, resilient, and liveable residential communities, supporting both the environment and the quality of life for residents. The case studies mentioned earlier highlight the positive outcomes and impacts of green infrastructure projects in residential settings, showcasing the potential effectiveness of integrating nature-based solutions into urban developments and how green infrastructure can effectively address urban challenges, enhance environmental quality, and create more sustainable and liveable residential communities.

Notes for Editor

This paper was previously submitted to another journal but was not accepted. Since then, I have revised and enhanced the content significantly to meet the scope and standards of your journal. Thank you for considering my submission.

References

Abera, L. E., Surbeck, C. Q., Alexander, K. (2021). Evaluating the effect of city ordinances on the implementation and performance of green stormwater infrastructure (GSI). *Environmental Challenges* 4; 100183. https://doi.org/10.1016/j.envc.2021.100183.

Albrechts, L., Balducci, A., Hillier, J. (eds) (2017). Situated practices of strategic planning: an international perspective. Routledge, London/New York.

Almulhim, A.I., Sharifi, A., Aina, Y.A., Ahmad, S., Mora, L., Filho, W.L., & Abubakar, I.R. (2024). Charting sustainable urban development through a systematic review of SDG11 research. *Nature Cities* 1, 677–685. https://doi.org/10.1038/s44284-024-00117-6

Anguelovski, I., Connolly, J. J. T., Masip, L., Pearsall, H. (2018). Assessing green gentrification in historicallydisenfranchised neighborhoods: A longitudinal and spatial analysis of Barcelona. *Urban Geogr.* 39, 458–491.

Artmann, M., Bastian, O., Grunewald, K. (2017). Using the Concepts of Green Infrastructure and Ecosystem Services to Specify Leitbilder for Compact and Green Cities—The Example of the Landscape Plan of Dresden (Germany). *Sustainability* 9, 198.

Ashinze, U. K., Edeigba, B. A., Umoh, A. A., Biu, P. W. & Daraojimba, A. I. (2024). Urban green infrastructure and its role in sustainable cities: A comprehensive review. *World Journal of Advanced Research and Reviews*, 21(2), 928–936. https://doi.org/10.30574/wjarr.2024.21.2.0519

Aswani, K. (2023, September 28). The benefits of green infrastructure investments in urban planning. Global Commons Part on Earth.org. https://earth.org/the-benefits-of-green-infrastructure-investments-in-urban-planning/

Bozovic, R., Maksimovic, Č., Mijic, A., Smith, K. M., Suter, I., & Van Reeuwijk, M. (2017). Blue Green Solutions. A Systems Approach to Sustainable, Resilient and Cost-Efficient Urban Development. https://doi.org/10.13140/RG.2.2.30628.07046

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., De Vries, S., Flanders, J. (2019). Nature and mental health: An ecosystem service perspective. *Sci. Adv*. 5, eaax0903. doi: 10.1126/sciadv. aax0903.

Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., Fisher-Jeffes, L. N., Ghisi, E., Rahman, A., Furumai, H., Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water Res. 115:195-209. Doi: 10.1016/j.watres.2017.02.056. *Erratum in: Water Res*.; 121:386. PMID: 28279940.

Chen, W., Wang, W., Huang, G., Wang, Z., Lai, C., Yang, Z. (2021). The Capacity of Grey Infrastructure in Urban Flood Management: A Comprehensive Analysis of Grey Infrastructure and the Green-Grey Approach. *Int. J. Disaster Risk Reduct*. 54, 102045.

Chenoweth, J., Anderson, A.R., Kumar, P., Hunt, W. F., Chimbwandira, S. J., Moore, T. L. C., (2018). The interrelationship of green infrastructure and natural capital. *Land Use Policy* 75, 137–144. https://doi.org/10.1016/j.landusepol.2018.03.021.

Conway, T. M., Khan, A., and Esak, N. (2020). An analysis of green infrastructure in municipal policy: divergent meaning and terminology in the Greater Toronto Area. *Land Use Policy 99*, 104864. doi: 10.1016/j.landusepol.2020.104864.

Coppes, B. A. (2021, June 8). The challenges of stormwater management. Wastewater Digest. https://www.waterworld.com/wastewater/stormwater-management/article/14200759/the-challenges-of-stormwater-management

Corley, J., Okely, J. A., Taylor, A. M., Page, D., Welstead, M., Skarabela, B., et al. (2021). Home garden use during COVID-19: Associations with physical and mental wellbeing in older adults. *J. Environ. Psychol.* 73, 101545. doi: 10.1016/j.jenvp.2020.101545.

Cumming, G. S., Epstein, G. (2020). Landscape sustainability and the landscape ecology of institutions. *Landsc Ecol* 35:2613–2628.

Dai, Y., & Solangi, Y. A. (2023). Evaluating and Prioritizing the Green Infrastructure Finance Risks for Sustainable Development in China. *Sustainability*, 15(9), 7068. https://doi.org/10.3390/su15097068

Deitch, M. J., & Feirer, S. T. (2019). Cumulative impacts of residential rainwater harvesting on stormwater discharge through a peri-urban drainage network. *Journal of environmental management*, 243, 127–136. https://doi.org/10.1016/j.jenvman.2019.05.018

Derkzen, M. L., van Teeffelen, A. J., & Verburg, P. H. (2017). Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? *Landscape and Urban Planning*, 157, 106–130.

Dipeolu, A. A., & Ibem, E. O. (2020). Green infrastructure quality and environmental sustainability in residential neighbourhoods in Lagos, Nigeria. *International Journal of Urban Sustainable Development*, 12(3), 267–282. https://doi.org/10.1080/19463138.2020.1719500

Djenontin, I. N. S., & Meadow, A. M. (2018). The art of co-production of knowledge in environmental sciences and management: Lessons from international practice. *Environmental Management*, 61(6), 885–903. https://doi.org/10.1007/s00267-018-1028-3

Drescher, M., and Sinasac, S. (2021). Social-psychological determinants of the implementation of green infrastructure for residential stormwater management. *Environ. Manage.* 67, 308–322. doi: 10.1007/s00267-020-01393-3.

Garbanzos, S., & Maniquiz-Redillas, M. (2022). Modeling the Hydrologic Performance and Cost-Effectiveness of LID in a Residential Park Area Using a Decentralized Design Approach. *Hydrology*, 9, 62. https://doi.org/10.3390/ hydrology9040062

Gradinaru, S. R., Hersperger, A. M. (2019). Green infrastructure in strategic spatial plans: evidence from European urban regions. *Urban For Urban Green* 40:17–28.

Gren, A., & Andersson, E. (2018). Being efficient and green by rethinking the urban-rural divide—Combining urban expansion and food production by integrating an ecosystem service perspective into urban planning. *Sustain. Cities Soc.* 40, 75–82.

Hamel, P., & Tan, L. (2022). Blue-Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps. *Environmental management*, 69(4), 699–718. https://doi.org/10.1007/s00267-021-01467-w

Hathaway, J. M., Bean, E. Z., Bernagros, J. T., Christian, D. P., Davani, H., Ebrahimian, A., Fairbaugh, C. M., Gulliver, J. S., McPhillips, L. E., Palino, G., Strecker, E. W., Tirpak, R. A., Van Duin, B., Weinstein, N., & Winston, R. J. (2024). A Synthesis of Climate Change Impacts on Stormwater Management Systems: Designing for Resiliency and Future Challenges. *J. Sustain. Water Built Environ*., 10, 04023014.

Hawken, S., Rahmat, H., Sepasgozar, S. M. E., & Zhang, K. (2021). The SDGs, Ecosystem Services and Cities: A Network Analysis of Current Research Innovation for Implementing Urban Sustainability. *Sustainability*, 13(24), 14057. https://doi.org/10.3390/su132414057

Hendricks, M.D., Meyer, M.A., Gharaibeh, N.G., Van Zandt, S., Masterson, J., Cooper, J.T., Jr., & Berke, P. (2018). The development of a participatory assessment technique for infrastructure: Neighborhood-level monitoring towards sustainable infrastructure systems. *Sustain. Cities Soc*. 38, 265–274.

Herath, P., Bai, X. (2024). Benefits and co-benefits of urban green infrastructure for sustainable cities: six current and emerging themes. *Sustainability Science* 19, 1039–1063. https://doi.org/10.1007/s11625-024-01475-9

Isola, F., Lai, S., Leone, F., & Zoppi, C. (2024). Urban Green Infrastructure and Ecosystem Service Supply: A Study Concerning the Functional Urban Area of Cagliari, Italy. *Sustainability*, 16(19), 8628. https://doi.org/10.3390/su16198628

Jabbar, M., Yusoff, M. M., and Shafie, A. (2022). Assessing the role of urban green spaces for human wellbeing: a systematic review. *GeoJournal* 87:4405–4423. https://doi.org/10.1007/s10708-021-10474-7.

Jia, J., and Zhang, X. (2021). A human-scale investigation into economic benefits of urban green and blue infrastructure based on big data and machine learning: A case study of Wuhan. *Journal of Cleaner Production*, Volume 316, 128321, ISSN 0959-6526. https://doi.org/10.1016/j.jclepro.2021.128321.

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, 21(2). https://www.jstor.org/stable/26270403

Khalili, S., Kumar, P., & Jones, L. (2024). Evaluating the benefits of urban green infrastructure: Methods, indicators, and gaps. *Heliyon*, 10(19), e38446. https://doi.org/10.1016/j.heliyon.2024.e38446

Kim, D., & Song, S. K. (2019). The Multifunctional Benefits of Green Infrastructure in Community Development: An Analytical Review Based on 447 Cases. *Sustainability* 11, 3917; doi:10.3390/su11143917.

Klein, Y., Lindfors, P., Osika, W., Magnusson Hanson, L.L., Stenfors, C.U.D. (2022). Residential Greenspace Is Associated with Lower Levels of Depressive and Burnout Symptoms, and Higher Levels of Life Satisfaction: A Nationwide Population-Based Study in Sweden. *Int. J. Environ. Res. Public Health,* 19, 5668. https://doi.org/10.3390/ ijerph19095668.

Kloos, J., Renaud, F.G., (2016). Overview of ecosystem-based approaches to drought risk reduction targeting small-scale farmers in sub-saharan africa. In Advances in Natural and Technological Hazards Research; Springer: Cham, Switzerland. Volume 42, pp.199–226.

Knaus, M., & Haase, D. (2020). Green roof effects on daytime heat in a prefabricated residential neighbourhood in Berlin, Germany. *Urban Forestry & Urban Greening* 53; 126738. https://doi.org/10.1016/j.ufug.2020.126738.

Kordana, S., & Slys, D. (2020). An analysis of important issues impacting the development of stormwater management systems in Poland. *Sci. Total. Environ*. 727, 138711.

Langemeyer, J., Wedgwood, D., McPhearson, T, Baro, F., Madsen, A. L., & Barton, D. N. (2020). Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona. *Science of The Total Environment.* Volume 707, 135487, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2019.135487.

Loveday, J., Morrison, G. M., & Martin, D. A. (2022). Identifying Knowledge and Process Gaps from a Systematic Literature Review of Net-Zero Definitions. *Sustainability*, 14(5), 3057. https://doi.org/10.3390/su14053057

Maqsoom, A., Aslam, B., Ismail, S., Thaheem, M.J., Ullah, F., Zahoor, H., Musarat, M.A., Vatin, N. I. (2021). Assessing Rainwater Harvesting Potential in Urban Areas: A Building Information Modelling (BIM) Approach. *Sustainability* 13, 12583.

Matsler, A. M., Meerow, S., Mell, I. C., and Pavao-Zuckerman, M. A. (2021). A ‘green’ chameleon: Exploring the many disciplinary definitions, goals, and forms of “green infrastructure”. *Landsc. Urban Plann*. 214, 104145. doi: 10.1016/j.landurbplan.2021.104145

Meierdiercks, K.L., & McCloskey, N. (2022). The Effectiveness of Centralized versus Decentralized Green Infrastructure in Improving Water Quality and Reducing Flooding at the Catchment Scale. *Journal of Water Management Modelling*.

Mell, I. (2022). Examining the role of Green Infrastructure as an advocate for regeneration. *Frontiers in Sustainable Cities*.

Mell, I., & Clement, S. (2019). Progressing Green Infrastructure planning: understanding its scalar, temporal, geo-spatial and disciplinary evolution. *Impact Assessment and Project Appraisal*, 38(6), 449–463. https://doi.org/10.1080/14615517.2019.1617517

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, 5(1). https://doi.org/10.1080/23311886.2019.1653531

Milovanovic, A., Rodic, D., Maruna, M. (2020). Eighty-year overview of the evolution of landscape ecology from a spatial planning perspective. *Landsc Ecol* 35:2141–2161.

Monteiro, R., Ferreira, J. C., & Antunes, P. (2022). Green Infrastructure Planning Principles: Identification of Priorities Using Analytic Hierarchy Process. *Sustainability*, 14(9), 5170. https://doi.org/10.3390/su14095170

Morash, J., Wright, A., LeBleu, C., Meder, A., Kessler, R., Brantley, E., & Howe, J. (2019). Increasing Sustainability of Residential Areas Using Rain Gardens to Improve Pollutant Capture, Biodiversity and Ecosystem Resilience. *Sustainability* 11, 3269; doi:10.3390/su11123269.

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I., Wilkinson, M. E., & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of The Total Environment*, 579, 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

O’Donnell, E. C., Netusil, N. R., Chan, F. K. S., Dolman, N. J., & Gosling, S. N. (2021). International Perceptions of Urban Blue-Green Infrastructure: A Comparison across Four Cities. *Water*, 13(4), 544. https://doi.org/10.3390/w13040544

Opdam, P. (2020). Navigating the space between landscape science and collective action for sustainability: identifying key factors in information processing. *Landsc Ecol* 35:2629–2639.

Opdam, P., Luque, S., Nassauer, J., Verburg, P. H., Wu, J. (2018). How can landscape ecology contribute to sustainability science? *Landsc Ecol* 33(1):1–7.

Osei, G., Pascale, F., Delle-Odeleye, N., Pooley, A. (2022). Green Infrastructure. In: The Palgrave Encyclopedia of Urban and Regional Futures. *Palgrave Macmillan, Cham*. https://doi.org/10.1007/978-3-030-51812-7_260-1

Pamukcu-Albers, P., Ugolini, F., La Rosa, D., Grădinaru, S. R., Azevedo, J. C., & Wu, J. (2021). Building green infrastructure to enhance urban resilience to climate change and pandemics. *Landscape Ecology*, 36(3), 665–673. https://doi.org/10.1007/s10980-021-01212-y.

Parker, J., Zingoni de Baro, M.E. (2019). Green infrastructure in the urban environment: A systematic quantitative review. *Sustainability*, 11, 3182

Pinto, L.V., Inácio, M., & Pereira, P. (2023). Green and Blue Infrastructure (GBI) and Urban Nature-based Solutions (NbS) contribution to human and ecological wellbeing and health. *Oxford Open Infrastructure and Health*.

Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023). Rainwater Harvesting and Treatment: State of the Art and Perspectives. *Water*, *15*(8), 1518. https://doi.org/10.3390/w15081518

Rall, E., Hansen, R., Pauleit, S. (2019). The added value of public participation GIS (PPGIS) for urban green infrastructure planning. *Urban For Urban Green* 40:264–274.

Ran, J. & Tang, M. (2018). Passive cooling of the green roofs combined with night-time ventilation and walls insulation in hot and humid regions. *Sustain. Cities Soc.* 38, 466–475.

Razzaghmanesh, M., & Borst, M. (2019). Long-term effects of three types of permeable pavements on nutrient infiltrate concentrations. *The Science of the total environment*, *670*, 893–901. https://doi.org/10.1016/j.scitotenv.2019.03.279

Romeiko X. X. (2020). Assessing Health Impacts of Conventional Centralized and Emerging Resource Recovery-Oriented Decentralized Water Systems. *International journal of environmental research and public health*, 17(3), 973. https://doi.org/10.3390/ijerph17030973

Saadatinavaz, F., Alomari, M.A., Ali, M. and Saikaly, P.E. (2024), Striking a Balance: Decentralized and Centralized Wastewater Treatment Systems for Advancing Sustainable Development Goal 6. *Adv. Energy Sustainability Res.*, 5: 2400097. https://doi.org/10.1002/aesr.202400097

Sang, J., & Pan, L. (2024). Impact of Green Infrastructure Investment on Urban Carbon Emissions in China. *Sustainability*, 16(7), 2668. https://doi.org/10.3390/su16072668

Sayli, U. M. and Berjis, D. (2021). "Blue-Green Infrastructure: An Opportunity for Indian Cities," ORF Occasional Paper No. 317, *Observer Research Foundation.*

Semeraro, T., Aretano, R., & Pomes, A. (2017). Green Infrastructure to Improve Ecosystem Services in the Landscape Urban Regeneration. *IOP Conference Series: Materials Science and Engineering*, 245(8). https://doi.org/10.1088/1757-899X/245/8/082044

Shafique, M. & Kim, R. (2017). Retrofitting the Low Impact Development Practices into Developed Urban areas Including Barriers and Potential Solution. *Open Geosci*. 9, 240–254.

Słyś, D., & Stec, A. (2020). Centralized or Decentralized Rainwater Harvesting Systems: A Case Study. *Resources*, 9(1), 5. https://doi.org/10.3390/resources9010005

Sokolova, M. V., Fath, B. D., Grande, U., Buonocore, E., & Franzese, P. P. (2024). The Role of Green Infrastructure in Providing Urban Ecosystem Services: Insights from a Bibliometric Perspective. *Land*, 13(10), 1664. https://doi.org/10.3390/land13101664

Soni, L., Alam, B., Bano, H., & Sadiq, M. I. (2024). Integrating green infrastructure in urban planning: A case study approach. *Journal of Xi'an Shiyou University, Natural Science Edition*, 20(6), 621–632.

Tansar, H., Li, F., Zheng, F., & Duan, H. (2024). A critical review on optimization and implementation of green-grey infrastructures for sustainable urban stormwater management. *AQUA — Water Infrastructure, Ecosystems and Society*, 73 (6): 1135–1150. doi: https://doi.org/10.2166/aqua.2024.310

Tappert, S., Kloti, T., & Drilling, M, (2018). Contested urban green spaces in the compact city: The re-negotiation of urban gardening in Swiss cities. *Landscape Urban Planning* 170; 69-78. http://dx.doi.org/10.1016/j.landurbplan.2017.08.016

Toxopeus, H. & Polzin, F. (2021). Reviewing financing barriers and strategies for urban nature-based solutions, *J. Environ. Manage.* 289, 112371. https://doi.org/10.1016/j.jenvman.2021.112371

Truong, S., Gray, T., & Ward, K. (2022). Enhancing urban nature and place-making in social housing through community gardening. *Urban Forestry & Urban Greening* 72; 127586. https://doi.org/10.1016/j.ufug.2022.127586.

Twohig, C., Casali, Y., & Aydin, N. Y. (2022). Can green roofs help with stormwater floods? A geospatial planning approach. *Urban Forestry & Urban Greening* 76. h ttps://doi.org/10.1016/j.ufug.2022.127724.

U.S. Environmental Protection Agency, Jefferson County Department of Community Development, "Introduction to Low Impact Development (LID)" USEPA, PO-00J08601, Accessed on 30 Jan, 2024. http://www.co.jefferson.wa.us/commdevelopment/PDFS/SquareONE/LID_intro_Sq1.pdf

U.S. Environmental Protection Agency. (2024, August 27). Benefits of green infrastructure. Retrieved from https://www.epa.gov/green-infrastructure/benefits-green-infrastructure

U.S. Environmental Protection Agency. (2024, January 31). Climate adaptation and stormwater runoff. U.S. Environmental Protection Agency. https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff

Ugolini, F., Massetti, L., Calaza-Martínez, P., Cariñanos, P., Dobbs, C., Ostoic, S.K., Marin, A. M., Pearlmutter, D., Saaroni, H., Šaulienė, I., Simoneti, M., Verlič, A., Vuletić, D., Sanesi, G. (2020). Effects of the COVID-19 pandemic on the use and perceptions of urban green space: an international exploratory study. Urban For *Urban Green* 56:126888.

Wan, C., Shen, G.Q., & Choi, S. (2018). The moderating effect of subjective norm in predicting intention to use urban green spaces: A study of Hong Kong. *Sustain. Cities Soc.* 37, 288–297.

Wang, D. X. Xu, P., An, B., & Guo, Q. (2024). Urban Green Infrastructure: Bridging Biodiversity Conservation and Sustainable Urban Development through Adaptive Management Approach. *Urban Ecology*, Volume 12.

Wilo. (2024, July 4). Globalisation & urbanisation: Green infrastructure – Sustainable approaches for cities. Retrieved from https://wilo.com/en/Pioneering/Stories/Green-infrastructure_42752.html

Xiao, X.D. (2018). The influence of the spatial characteristics of urban green space on the urban heat island effect in Suzhou Industrial Park. *Sustain. Cities Soc*. 40, 428–439.

Yin, D., Xu, C., Jia, H., Yang, Y., Sun, C., Wang, Q., Liu, S. (2022). Sponge City Practices in China: From Pilot Exploration to Systemic Demonstration. *Water* 14, 1531. https://doi.org/10.3390/w14101531

Ying, J., Zhang, X., Zhang, Y., & Bilan, S. (2021). Green infrastructure: systematic literature review. *Economic Research-Ekonomska Istraživanja*, 35(1), 343–366. https://doi.org/10.1080/1331677X.2021.1893202

Zamiri, M., & Esmaeili, A. (2024). Methods and Technologies for Supporting Knowledge Sharing within Learning Communities: A Systematic Literature Review. *Administrative Sciences*, 14(1), 17. https://doi.org/10.3390/admsci14010017

Zhang, Y., Zhao, W., Chen, X., Jun, C., Hao, J., Tang, X., Zhai, J. (2021). Assessment on the Effectiveness of Urban Stormwater Management. *Water* 13, 4. https://dx.doi.org/10.3390/ w13010004

Ziogou, I. (2018). Implementation of green roof technology in residential buildings and neighborhoods of Cyprus. *Sustain. Cities Soc*. 40, 233–243.

Zuniga-Teran, A. A., Staddon, C., de Vito, L., Gerlak, A. K., Ward, S., Schoeman, Y., … Booth, G. (2019). Challenges of mainstreaming green infrastructure in built environment professions. *Journal of Environmental Planning and Management*, 63(4), 710–732. https://doi.org/10.1080/09640568.2019.1605890

Zwierzchowska, I., Fagiewicz, K., Ponizy, L., Lupa, P., & Mizgajski, A. (2019). Introducing nature-based solutions into urban policy – facts and gaps. Case study of Poznań. *Land Use Policy* 85; 161–175. https://doi.org/10.1016/j.landusepol.2019.03.025.