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# Toward Climate-Resilient Cities: A Review of Nature-based Solutions for Urban Flood Management

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## Abstract

Urban flooding represents one of the most pressing challenges for cities worldwide, exacerbated by climate change and rapid urbanization. Conventional grey infrastructure often proves inadequate in addressing these complex hydrological threats, prompting increased attention to Nature-based Solutions (NbS) as sustainable alternatives. This comprehensive review examines the role of NbS in advancing climate-resilient urban development through effective flood management. Analyzing 42 peer-reviewed studies selected through systematic screening, we identify key implementation trends across geographic regions and climatic contexts. The evidence demonstrates that NbS strategies—including sponge city concepts, green infrastructure, and blue-green corridors—can reduce stormwater runoff by 30-75% while providing significant co-benefits such as enhanced biodiversity, urban heat island mitigation, and improved public well-being. However, substantial barriers persist, including institutional fragmentation, limited funding mechanisms, and regulatory constraints. Successful implementation requires integrated governance approaches, updated planning frameworks, dedicated financial instruments, and meaningful community engagement. This review concludes that NbS represent not merely complementary measures but essential components of climate adaptation strategies, offering multifunctional pathways toward creating more resilient, sustainable, and livable urban environments.

## Keywords

Nature-based Solutions; Blue-Green Infrastructure; Flood Resilience; Sustainable Cities; Spatial Planning

## 1. Introduction

Cities face a range of unavoidable challenges induced by rapid urbanization, most notably the intensifying effects of climate change and the degradation of natural resources [1, 2]. As the global urban population is projected to increase from 55% to 68% by 2050, approximately 19% of urban residents are expected to live in areas vulnerable to climate-related hazards [3, 4]. Among these hazards, urban flooding has become one of the most significant contributors to global disaster-related losses, posing severe socio-economic and environmental disruptions [5-7]. The repercussions are extensive, encompassing billions of dollars in economic damages, widespread displacement, and escalating humanitarian crises—particularly in developing regions where infrastructure and governance mechanisms remain under-resourced and fragmented.

The social implications of flood events are especially profound. Vulnerable populations—often concentrated in informal or inadequately planned settlements—bear a disproportionate share of the impacts, facing higher rates of displacement, property loss, and challenges in post-disaster recovery. This disparity in risk exposure between high- and low-income

regions underscores the intersection of climate vulnerability and social inequality [8, 9]. In many low-income countries, floods not only destroy physical assets and infrastructure but also undermine educational opportunities, public health systems, and economic livelihoods.

Historically, flood management strategies have relied heavily on structural interventions such as levees, embankments, and drainage systems. Although these engineered solutions can provide temporary protection, they are limited in scope, costly to maintain, and often foster a false sense of security [9]. As a result, contemporary perspectives on urban resilience increasingly emphasize the importance of adopting holistic, adaptive approaches that integrate structural and non-structural strategies to address the underlying causes of flood vulnerability [10].

Within this paradigm, spatial planning has emerged as a critical non-structural instrument for flood risk management [11, 12]. It encompasses land-use policies, zoning regulations, and the preservation of natural floodplains, all aimed at proactively reducing exposure and enhancing adaptive capacity. Nature-based Solutions (NbS) have gained significant attention as effective spatial planning mechanisms [13]. By emulating natural hydrological processes, NbS provides decentralized, resilient, and cost-effective alternatives to traditional flood management methods [8]. Cities worldwide have begun adopting innovative frameworks such as Low-Impact Development (LID), Sponge City principles, and Water-Sensitive Urban Design (WSUD), recognizing the necessity of harmonizing urban growth with ecological sustainability [12, 14, 15].

This study advances the role of NbS as a strategic approach to fostering flood-resilient cities by integrating natural processes into built environments. The paper is structured into four main sections: (1) an overview of spatial planning tools for flood risk reduction; (2) an analysis of the role and benefits of NbS in mitigating flood impacts; (3) a review of pioneering international case studies; and (4) a concluding discussion proposing actionable mechanisms for incorporating NbS into existing metropolitan planning frameworks.

## 2. Concise Overview

### 2.1 Classification of Natural Disasters

Natural disasters are categorized into six main types: geophysical, hydrological, meteorological, climatological, biological, and extraterrestrial [16, 17]. Geophysical phenomena include earthquakes, mass movement, and volcanic activity [18]. Hydrological phenomena like floods, landslides, and wave actions [17]. Meteorological phenomena encompass storms, extreme temperatures, and fog. Climatological phenomena include drought, glacial lake outbursts, and wildfires [19, 20]. Biological phenomena include animal accidents, epidemics, and insect infestations, whereas extraterrestrial impacts encompass space weather. During 1980-2019, geophysical disasters represented 10% of occurrences, 3% of deaths, and 4% of economic losses, while hydrological disasters accounted for about 48% of all natural disasters. Meteorological and climatological disasters scored approximately 34% and 8% of all disasters, respectively.

### 2.2 Flood Mitigation Strategies

Urban flooding occurs when water exceeds the natural or designed capacity of a city's drainage systems, often as a result of heavy rainfall, rapid snowmelt, dam failures, or a combination of these factors [21, 22]. The frequency and severity of such events have surged in recent years, primarily due to the combined effects of climate change and human activities. Changes in precipitation patterns, the intensification of the hydrological cycle, and melting polar ice have significantly increased global flood events. Concurrently, rapid and unplanned urbanization has led to the expansion of impermeable surfaces, disrupted natural water flows, and heightened vulnerability in densely populated and poorly managed areas. Floods can be classified into several types based on their origin and the areas they affect. Coastal floods are caused by extreme tidal conditions such as storm surges or hurricanes along shorelines [23]. Fluvial flooding occurs when rivers exceed their capacity due to prolonged rainfall, often resulting in overbank or sudden flash floods [24]. Pluvial floods arise when short, intense rainfalls overwhelm urban drainage systems. The impact of flooding is assessed through three dimensions: hazard (the nature and intensity of the flood), exposure (the presence of people and assets in flood-prone areas), and vulnerability (the capacity to withstand and recover from flooding). As shown in Figure 1, flood risk management measures (FRMMs) are employed to mitigate flood risk, which include both structural solutions and non-structural strategies [25].

**Figure 1. Flood risk management measures are categorized into structural interventions (e.g., dams, levees, floodwalls, and drainage systems) and non-structural strategies (e.g., land-use planning, zoning regulations, insurance schemes, and early warning systems), all designed to reduce hazard exposure, strengthen preparedness, and promote long-term resilience to flooding.**

## 3. Systematic Literature of NbS and Interventions

The systematic review was conducted following the PRISMA 2020 framework, including three sequential phases. First, comprehensive keyword-based searches were performed across major scientific databases to capture all potentially relevant studies. Second, duplicate records were removed, and titles and abstracts were systematically screened to evaluate their consistency with the predefined inclusion criteria. Finally, the full texts of eligible publications were examined, thematically classified, and synthesized to derive evidence-based insights, as detailed below:

### 3.1 Search Strategy and Data Extraction

Research on NbS for flood resilience is inherently interdisciplinary, intersecting urban planning, environmental science, hydrology, and climate change adaptation. To capture this diversity, we adopted a broad yet targeted keyword strategy, combining terms such as "Nature-Based Solutions," "Blue-Green Infrastructure," "Urban Flooding," "Low-Impact Development," "Urban Resilience," and "Spatial Planning." Searches were conducted across leading academic databases known for their extensive peer-reviewed coverage and robust indexing standards, including Scopus, Web of Science, ScienceDirect, Taylor & Francis, Wiley, Springer, MDPI, JSTOR, ASCE Library, and Nature. These platforms collectively ensured access to both theoretical and applied studies across disciplines. No publication year restrictions were imposed, but only peer-reviewed articles and reviews written in English were retained. The retrieved records were organized and analyzed using VOSviewer, a bibliometric mapping tool that enables clustering and visualization of keyword co-occurrence, co-citation patterns, and thematic networks, as shown in Figure 2. Keywords occurring at least ten times were included in the mapping process, allowing for the identification of dominant research clusters and thematic linkages relevant to NbS and flood resilience.

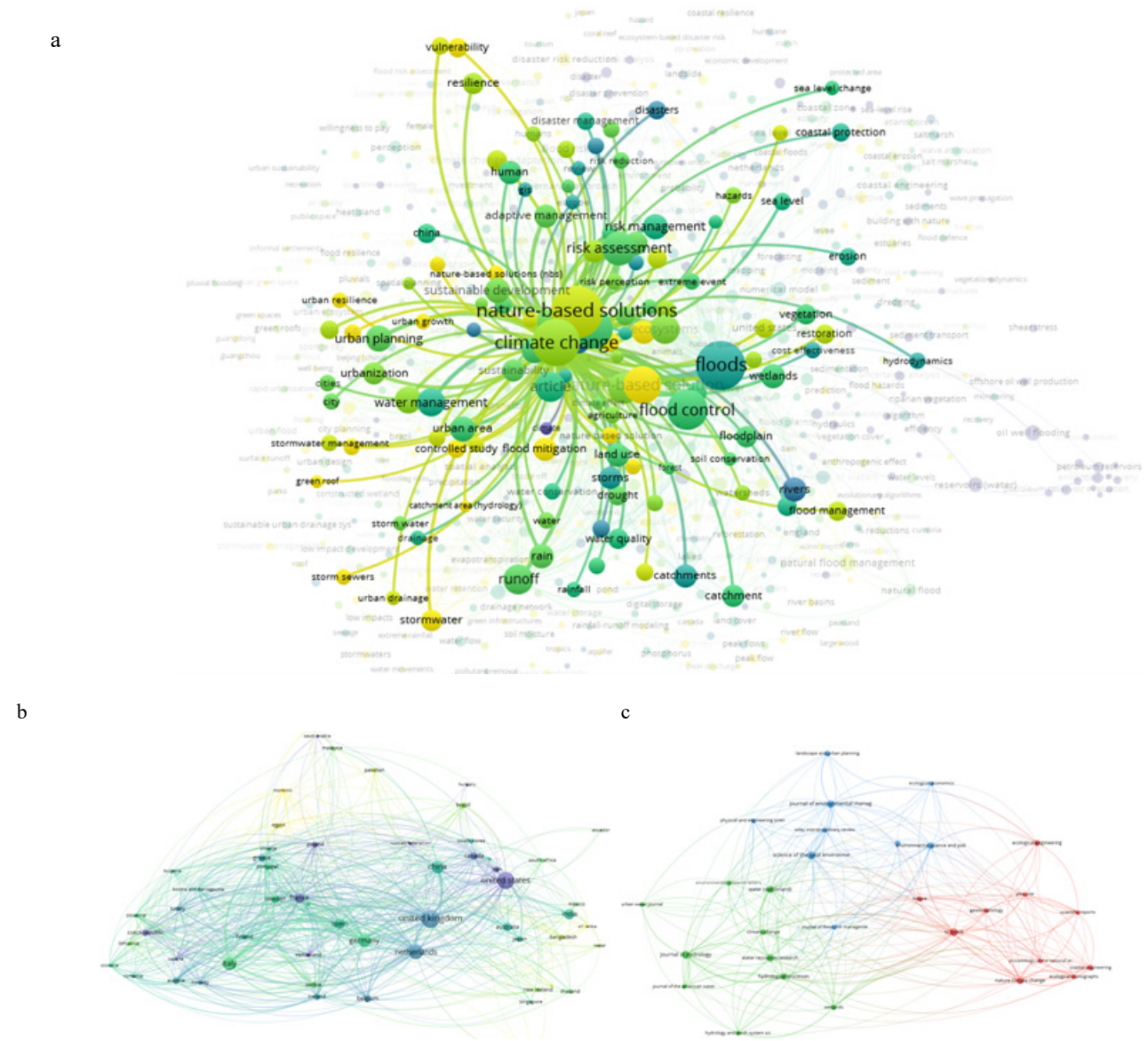


**Figure 2. Bibliometric network visualizations of research on NbS and flood resilience. (a) The top image presents a co-occurrence keyword network, where node size indicates the frequency of keywords and link strength reflects their co-occurrence relationships; node colors correspond to the average year of publication; (b) Country-level collaboration networks, highlighting the geographic distribution and strength of international research partnerships; (c) Journal co-citation analysis, clustering journals into distinct thematic groups that reflect disciplinary orientations and knowledge domains contributing to NbS and flood resilience research.**

## 3.2 Screening, Inclusion, and Exclusion Process

The initial search yielded 507 records. After removing duplicates, titles and abstracts were screened for relevance. The full texts of the remaining articles were then assessed against predefined inclusion criteria. Studies were included if they: (i) explicitly focused on NbS strategies for urban flood mitigation; (ii) were set in urban or peri-urban contexts; and (iii) provided empirical data, case study analysis, or theoretical frameworks relevant to planning and implementation. This process resulted in 42 studies for final synthesis (see Figure 3: PRISMA Flow Diagram). Bibliometric mapping was performed using VOSviewer to visualize keyword co-occurrence and research trends.

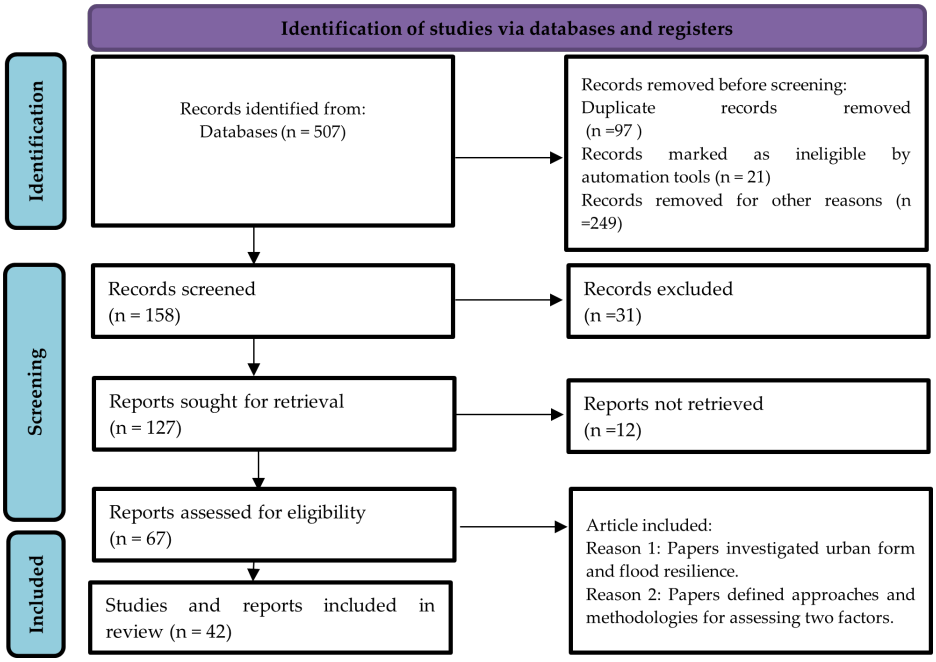


**Figure 3. Stages of a systematic literature review using the PRISMA method.**

## 4. Results and Discussion

The analysis indicates a significant rise in scholarly interest in NbS over the past decade, particularly since 2012. The number of publications in this area has grown more than tenfold between 2012 and 2022. Journals such as Water, Sustainability, Journal of Hydrology, and Science of the Total Environment have featured the majority of these studies. A review of the literature highlights a variety of NbS approaches and a conceptual framework (introduced through a Sankey diagram, as shown in Figure 4) that categorizes the connections between climate regions, intervention types, and intended objectives like mitigation, adaptation, and ecosystem services. Geographically, the distribution of NbS approaches varies significantly. For instance, Sponge City (SC) initiatives are predominantly found in China. At the same time, Green Infrastructure (GI) and Low Impact Development (LID) are more common in the U.S. Sustainable Urban Drainage Systems (SUDS) are applied in various continents, including Europe, Australia, and South America.

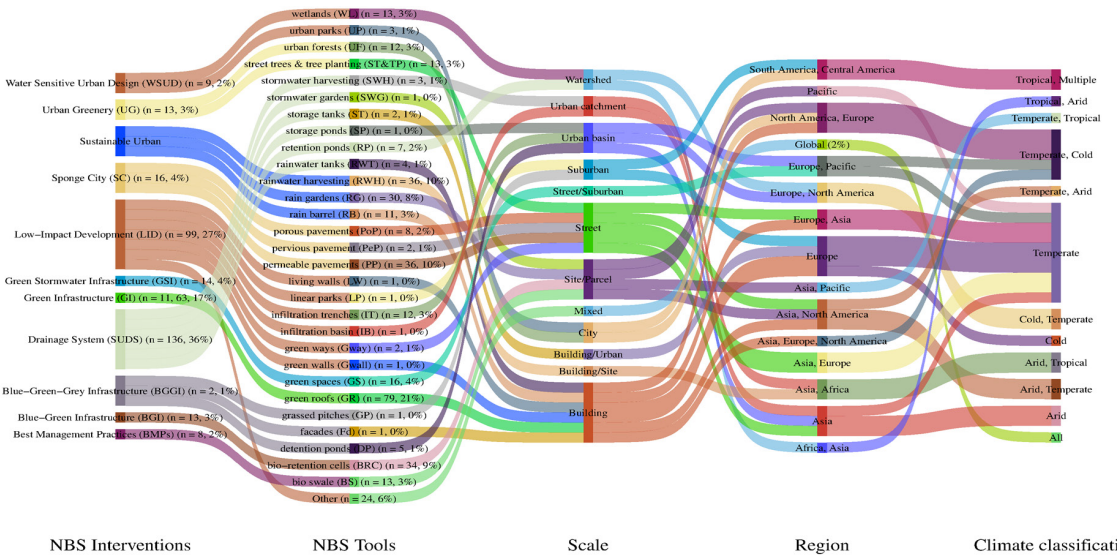


**Figure 4. Sankey diagram illustrating the proposed taxonomy of NbS, linking interventions, objectives, and contextual factors.**

### 4.1 The Multifunctionality Value of NbS in Urban Planning

NbS are designed to harness the power of natural processes to deliver a wide range of environmental, social, and economic co-benefits [26]. Their multifunctionality makes them especially valuable in addressing the complex and interconnected challenges that cities face today, including climate change, biodiversity loss, urban heat, water pollution, and public health concerns, as detailed below:

#### 4.1.1 Environmental Benefits

At their core, NbS support urban hydrology by mimicking natural systems to absorb, filter, and store stormwater. Green roofs, permeable pavements, bioswales, and wetlands slow runoff, reduce peak flow rates, and help recharge groundwater. This mitigates urban flooding and improves water quality by filtering pollutants and reducing combined sewer overflows (CSOs). Moreover, by restoring or replicating natural habitats, NbS supports urban biodiversity [12, 27]. For example, constructed wetlands and green corridors provide habitat for birds, amphibians, insects, and other wildlife, contributing to ecological connectivity within urban landscapes. In densely built environments, even small patches of green infrastructure can serve as critical ecological stepping-stones.

#### 4.1.2 Social and Public Health Benefits

Urban green spaces—such as rain gardens, parks, and water plazas—enhance public health and well-being. Research consistently shows that access to natural areas improves mental health, encourages physical activity, and fosters social interaction [26, 28, 29]. In flood-prone neighborhoods, NbS projects that double as public spaces manage stormwater and create attractive, multi-use environments for community gathering and recreation. These spaces help reduce heat stress, improve air quality, and serve as informal educational tools, promoting public awareness about sustainability and climate resilience. Crucially, NbS can play a role in advancing climate equity. When strategically located, especially in underserved or vulnerable communities, NbS can reduce disparities in access to green space and provide cooling and flood protection [30, 31].

#### 4.1.3 Economic Efficiency and Long-Term Value

Economically, NbS can be cost-effective alternatives—or valuable complements—to conventional grey infrastructure. While initial installation costs may be comparable or slightly higher, NbS often have lower life-cycle costs due to reduced maintenance, energy use, and environmental degradation. For instance, bioswales and rain gardens reduce the need for costly upgrades to sewer systems by naturally managing runoff at the source. At the same time, green roofs and trees help reduce building energy demand by improving insulation and shading, leading to lower utility bills.

Furthermore, the presence of NbS can stimulate local economic development. Property values typically increase near well-maintained green and blue infrastructure, while projects also create green jobs related to landscape management, ecological monitoring, and community engagement [13, 15]. As cities seek climate adaptation funding, NbS projects are often eligible for support from national governments and international development banks, especially when they offer measurable co-benefits across multiple sectors.

### 4.2 Effectiveness of NbS in Flood Resilience

NbS has emerged as a sustainable and multifunctional solution that works with natural hydrological processes rather than against them. The hydrological effectiveness of NbS lies in its ability to restore natural water absorption and retention capacities in urban areas, slow down stormwater runoff, increase infiltration rates, and reduce peak flows. Empirical studies demonstrate that well-implemented NbS systems can retain 40-90% of stormwater runoff, significantly decreasing flood risks [2]. For instance, sponge city initiatives in China have shown a 30-50% reduction in surface flooding during heavy rainfall events. Similarly, Portland's green infrastructure program achieved a 35% reduction in stormwater entering combined sewer systems [2, 32]. The widespread adoption of Best Management Practices (BMPs) for stormwater control became institutionalized across North America during the early 1990s, as evidenced by their integration into regional design standards [33]. As an advanced iteration of BMPs, LID emerged as a comprehensive approach to replicate natural hydrological processes through techniques like permeable surfaces, bioretention systems, and rainwater harvesting [34]. Research demonstrates that LID systems exhibit variable performance across different flood scenarios. These nature-based solutions prove effective for managing pluvial flooding through distributed stormwater retention [35], yet their capacity becomes constrained during extreme precipitation events that exceed design thresholds. This performance gap highlights the necessity for hybrid approaches that combine LID with conventional drainage infrastructure, particularly in flash flood-prone regions [36]. The systems' declining efficiency during high-intensity rainfall underscores the importance of context-specific flood management strategies. Empirical studies across diverse climates have quantified LID's hydrological benefits. Implementation cases show runoff reductions ranging from 30-75% in Brazilian watersheds to 47% in Chinese green infrastructure projects [37]. Specific techniques demonstrate remarkable efficacy—permeable pavements generate

94% less runoff than conventional surfaces, while optimized grassed swales provide cost-effective peak flow mitigation [38]. Regional applications reveal substantial impacts, including a 54.7% peak flow reduction in Algerian catchments and a 12.4% annual runoff decrease from Singaporean green roofs [37, 38].

### 4.3 Pioneering Case Studies in Integrating NbS into Cities' Planning

Leading cities around the world have launched pioneering experiments that combine natural water management with urban design to reduce flooding risks while enhancing livability. These efforts integrate green spaces, such as parks and green roofs, with blue elements like rivers, ponds, and stormwater channels to mimic natural hydrological processes, as shown in Table 1.

**Table 1. Pioneering Experiments Integrating NbS in Urban Planning**

| Project Name | Location | Description | Key Features | Outcomes |
|---|---|---|---|---|
| **Sponge City Initiative** | China | A national program to manage urban flooding using permeable surfaces, green roofs, and wetlands to absorb rainwater. | Permeable pavements, constructed wetlands, green roofs, and rain gardens. | Reduced flooding by 30% in pilot areas, improved water quality, and enhanced urban biodiversity. |
| **Green Heart of Lisbon** | Lisbon, Portugal | Transformation of underused urban spaces into green corridors and parks to enhance biodiversity and reduce heat island effects. | Urban forests, green corridors, and community gardens. | Lowered city temperatures by 2°C in targeted areas and increased green space access by 15%. |
| **High Line** | USA | Conversion of an abandoned railway into a linear park with native plantings to promote biodiversity and recreation. | Native plant landscaping, stormwater management, and public green space. | Attracted 8 million visitors annually, improved local air quality, and increased property values by 10%. |
| **Bishan-Ang Mo Kio Park** | Singapore | Restoration of a concrete canal into a naturalized river with bioengineered banks to manage flooding and enhance ecosystems. | River naturalization, bioengineered riverbanks, and recreational spaces. | Reduced flood risk, increased biodiversity by 20%, and improved community engagement. |
| **Medellín Green Corridors** | Colombia | Creation of 30 green corridors with tree planting and urban gardens to combat heat and air pollution. | Tree canopies, urban orchards, vertical gardens. | Reduced urban heat by 3°C, lowered PM2.5 levels by 10%, and engaged 50,000 residents in maintenance. |
| **Copenhagen Cloudburst Plan** | Denmark | A city-wide strategy to manage extreme rainfall through green infrastructure, including pocket parks and retention basins. | Rain gardens, green streets, water plazas, retention ponds. | Mitigated 90% of flood risks in targeted zones, increased green coverage by 10%, and enhanced urban resilience. |
| **Million Trees Initiative** | Melbourne, Australia | A plan to plant one million trees to increase canopy cover, reduce urban heat, and improve air quality. | Urban tree planting, green roofs, and community-led greening projects. | Increased canopy cover by 20%, reduced summer temperatures by 1.5°C, and sequestered 500 tons of $CO_2$ annually. |
| **Nairobi River Restoration** | Kenya | Restoration of the Nairobi River through wetland creation and riparian planting to improve water quality and biodiversity. | Constructed wetlands, riparian buffers, and community cleanup programs. | Improved water quality by 25%, restored 10 km of river habitat, and engaged 5,000 residents in conservation. |
| **Rotterdam Water Square** | Netherlands | A multifunctional urban plaza that stores rainwater during heavy rains and serves as a public space during dry periods. | Water retention basins, permeable surfaces, and green roofing. | Managed 80% of local stormwater, reduced urban flooding, and created a vibrant community space. |
| **Tokyo Green Space Plan** | Japan | Expansion of urban green spaces through rooftop gardens and vertical forests to mitigate heat and enhance biodiversity. | Rooftop gardens, vertical greening, and urban pocket parks. | Reduced the urban heat island effect by 1°C, increased green space by 12%, and supported 50+ native species. |

Source: Author based on [38, 40-46].

In Rotterdam, the Netherlands, one of the most well-known examples is the Water Squares, such as Benthemplein, which serve a dual purpose: public spaces in dry conditions and temporary retention basins during heavy rainfall. Similarly, Copenhagen launched its ambitious Cloudburst Management Plan after a devastating flood in 2011. This integrated approach uses surface features like green streets and parks, along with underground tunnels, to manage cloudburst events. Both cities show that NbS can be innovatively blended into public infrastructure and urban design to manage extreme rainfall events. Singapore has taken a holistic and aesthetic approach through its ABC Waters Programme, transforming sterile canals into vibrant community spaces that function as water retention zones and ecological corridors. These redesigned waterways not only reduce flood risks but also promote biodiversity and civic engagement. Meanwhile, Wuhan, China, has embraced the concept of a Sponge City, where urban surfaces are designed to absorb, retain, and reuse rainwater. This strategy is helping to recharge groundwater, reduce runoff, and mitigate floods in a rapidly urbanizing context, although it faces challenges in scaling and maintenance [39].

### 4.4 Obstacles and Restrictions to Implementing NbS

Despite the growing recognition of NbS as a vital component of sustainable and climate-resilient cities, its widespread implementation remains limited by a range of obstacles and institutional restrictions. One of the most persistent challenges is the dominance of conventional grey infrastructure paradigms in urban planning. Engineers, developers, and policymakers often default to traditional solutions like concrete stormwater drains, culverts, and flood barriers, which are familiar, standardized, and embedded in technical codes. This legacy mindset results in institutional inertia, making it difficult for nature-based approaches—despite their long-term cost-effectiveness and multifunctional benefits—to gain equal standing in project planning and budgeting. Another major barrier lies in fragmented governance and siloed responsibilities. Urban water management, green space planning, land development, and transportation often fall under different municipal departments or agencies that operate independently with little coordination. This institutional fragmentation hinders integrated planning, delays implementation, and limits the possibility of leveraging NbS's cross-cutting benefits. In addition, regulatory and legal frameworks are often outdated and do not accommodate or require nature-based designs. For instance, building codes may not include standards for permeable surfaces, bioswales, or green roofs, and zoning laws may restrict multifunctional land use. In many cities, land ownership patterns and the lack of space in dense urban environments further complicate NbS installation, especially in retrofitting older infrastructure [26, 31]. Financial limitations also represent a significant obstacle. Although NbS can be cost-effective over the long term, many cities struggle with short-term budget constraints, competing infrastructure priorities, and a lack of dedicated funding streams for green infrastructure. Additionally, because the benefits of NbS are often diffuse and hard to quantify in financial terms, they are frequently undervalued in cost-benefit analyses and overlooked in investment decisions. Moreover, a lack of technical capacity and trained professionals who understand the design, implementation, and maintenance of NbS can hinder efforts to scale up these solutions [14, 27]. In many cases, local governments also face difficulties engaging with communities and developers to promote awareness and buy-in for nature-based approaches.

### 4.5 Planning Mechanisms to Strengthen NbS in City Planning

Integrating NbS into urban planning requires more than ecological awareness; it calls for a deliberate set of planning tools and mechanisms that embed nature-based infrastructure into the urban fabric. These mechanisms help ensure that NbS is not treated as a peripheral amenity but as a core, functional part of resilient and livable cities, as shown in Figure 5. A foundational step in strengthening NbS is establishing clear and supportive policy and regulatory frameworks. Municipal and national governments must recognize NbS as essential urban infrastructure. To begin with, city master plans and long-term development strategies should explicitly include NbS as a strategic priority. This signals commitment and provides a roadmap for implementation across sectors. Municipalities can also adopt targeted ordinances requiring or incentivizing the inclusion of green roofs, permeable surfaces, and stormwater retention systems in both new developments and major retrofits. Environmental Impact Assessments (EIAs) provide another regulatory lever, ensuring that developments consider and mitigate their impact on existing NbS networks. In addition, cities can develop performance standards that set measurable goals for runoff retention, green coverage, and cooling capacity—standards that guide planning approvals and development permits. Land use planning and zoning mechanisms are equally critical in integrating NbS into the spatial structure of the city. Traditional zoning codes often fail to account for ecological processes or the multifunctionality of green and blue spaces [13, 47, 48]. Updated zoning regulations can designate specific areas for NbS, such as wetlands, riparian zones, or green corridors, protecting these ecosystems from incompatible development. Mandating a minimum

percentage of green space in various land use zones can ensure that NbS is built into every type of development. In land-constrained cities, planning systems require new developments to replace lost greenery with vertical or rooftop vegetation, maintaining ecological function in dense urban areas. Urban planning authorities can also use incentive-based zoning, allowing increased building density in exchange for the integration of public green infrastructure [48].

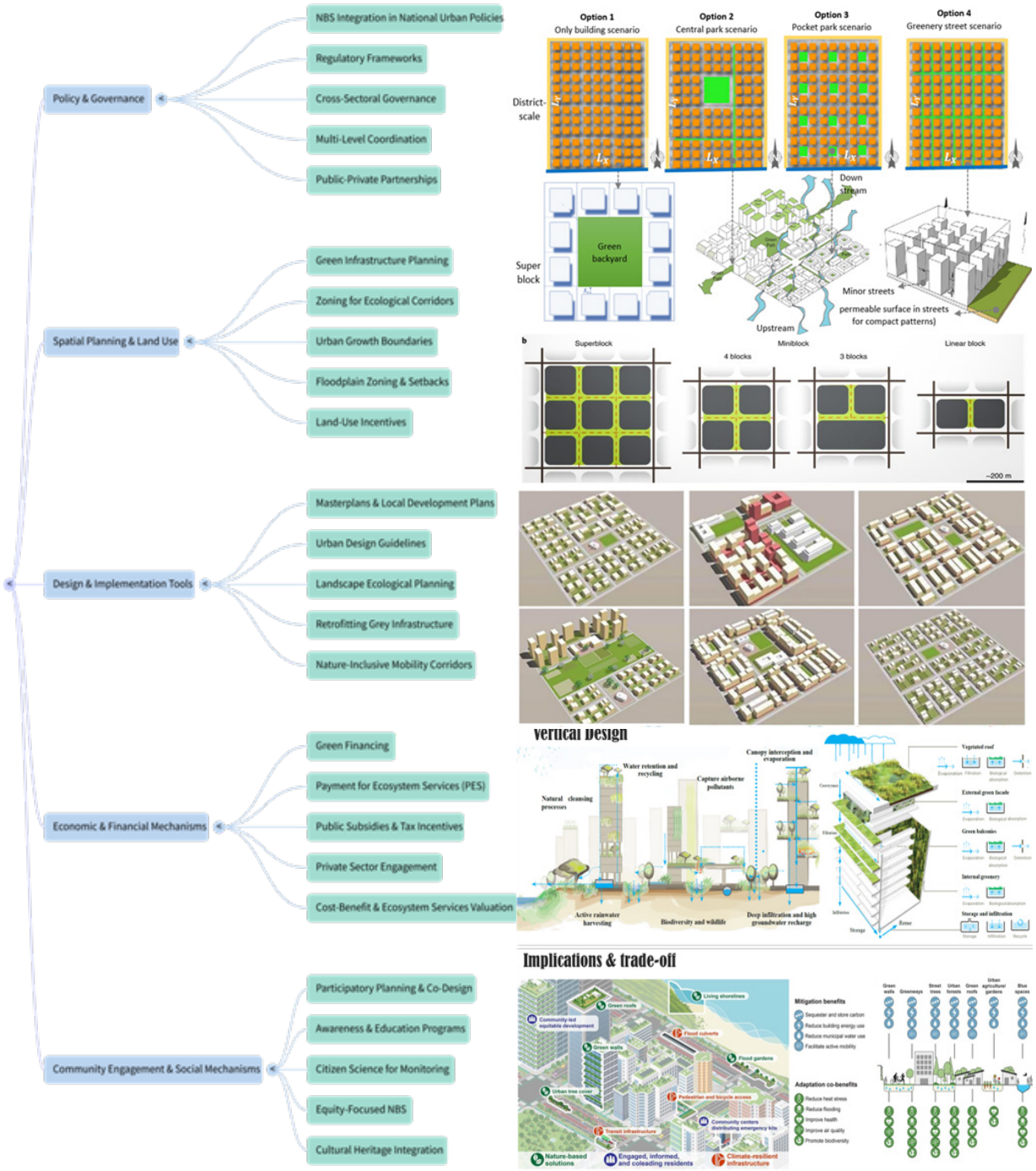


**Figure 5. Comprehensive framework for integrating NbS into urban planning and design, outlines five key pillars supported by visual examples of district-scale and vertical design scenarios.**

While firm policy and zoning are foundational, financial and economic mechanisms play a pivotal role in turning plans into reality. One of the most direct methods is public investment through dedicated green infrastructure funds or the issuance of green bonds, which provide upfront capital for large-scale NbS projects. Stormwater fee systems, increasingly adopted in North America and Europe, can also finance NbS. These systems charge property owners based on the impervious surfaces on their land and offer fee reductions or credits to those who install rain gardens, green roofs, or permeable pavements. Tax incentives and municipal grants can further motivate private investment in NbS, especially in high-risk or low-income areas. In some cities, public-private partnerships (PPPs) have proven effective, with private developers co-financing green infrastructure that benefits both their projects and the wider community. Effective implementation also demands collaboration among urban planners, water managers, environmental agencies, parks departments, and transportation authorities. Cities can foster this coordination through interdepartmental task forces or dedicated climate adaptation units. In other cases, decentralized or polycentric governance models distribute responsibilities across various stakeholders, including NGOs, research institutions, and community groups [40, 49, 50]. Monitoring and evaluation also play an essential role; cities need reliable data on the performance and condition of NbS assets. Investments in Geographic Information Systems (GIS) and digital modeling tools allow for more effective planning and maintenance. Additionally, building institutional capacity through training, technical guidance, and cross-sector dialogue ensures that public officials are equipped to plan and manage NbS effectively [51, 52].

Lastly, no urban infrastructure can be truly sustainable without community support. Community participation and co-design are critical planning mechanisms that enhance the social relevance, functionality, and durability of NbS. Public engagement during the design phase ensures that infrastructure reflects local needs and values. Participatory methods such as neighborhood design workshops, citizen mapping, and co-creation sessions foster a sense of ownership among residents. Beyond design, citizen science programs can involve the public in monitoring water levels, maintaining green infrastructure, collecting biodiversity data, and building environmental awareness. Equity-focused planning is also essential, particularly in underserved neighborhoods that are disproportionately affected by flooding. Educational campaigns, school programs, and public information efforts can further increase awareness and encourage everyday participation in the care and use of NbS. These mechanisms work collectively to embed ecological thinking into the core of urban development, making cities not only more flood-resilient but also more inclusive, biodiverse, and livable.

## 5. Conclusion

This review establishes Nature-based Solutions as fundamental to developing climate-resilient cities capable of managing increasing flood risks. The accumulated evidence confirms that NbS provide effective stormwater management while delivering crucial ecological, social, and economic co-benefits that extend far beyond flood mitigation. The analysis reveals that successful implementation hinges on addressing key barriers through policy integration, institutional coordination, and financial innovation. Moving forward, cities must prioritize NbS within broader climate adaptation strategies, recognizing their multifunctional value in creating urban environments that are not only flood-resistant but also more sustainable and equitable. Future efforts should focus on developing context-specific implementation frameworks, strengthening monitoring and evaluation systems, and fostering knowledge exchange across regions. As climate pressures intensify, the transition toward nature-positive urban development becomes increasingly urgent—not as an alternative to conventional approaches, but as an essential evolution in how we conceptualize, design, and manage climate-resilient cities for future generations.

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