

# Nature-Oriented Paradigms for Urban Water Security: Perspective on Framework, Scale, and Sector



Negin Balaghi-Ficzkowski, Nidhi Nagabhatla, and Tariq A. Deen

**Abstract** Water security in urban areas is threatened by a multitude of direct and indirect drivers. On the one hand, the demand for water is increasing on a daily basis as the urban population and lifestyle needs increase; on the other hand, events such as floods, tropical cyclones, and other natural hazards result in disruption of water provisioning systems and processes. Additionally, climate change impacts such as heat waves and sea-level rise affect the sustainability of water supplies in urban areas. Conventionally, hard engineering structures and strategies have been implemented around the world to address water needs in urban areas and solutions that are often costly and intrusive to the natural environment. Nature-based solutions (NBS) in the past years emerged as a framework for exploring the potential of soft engineering solutions—as an alternative for managing urban planning, building climate resilience, and sustaining water needs of the urban communities. In this chapter, the following points are explained: (a) review of selected nature-oriented conceptual framings and practical options that apply to urban water systems, (b) illustration of existing NBS practices such as permeable pavements, green roofs, and bioretention ponds in urban landscape architecture planning, and (c) future of urban landscapes with comparative context of traditional versus nature-based water management practices. The conclusion draws attention to the UN Decade on Ecosystem Restoration (2021–2030) that is aiming to prevent, halt, and reverse the degradation of ecosystems globally. The aim is to present a synthesis that can steer integrated development planning while addressing basic water needs, climate resilience, and ecosystems protection in all settings and particularly in urban landscapes.

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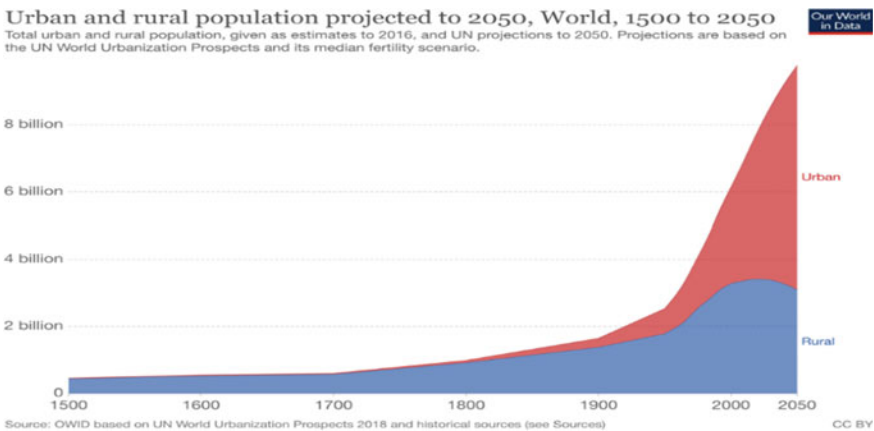
**Keywords** Urban water security · Nature-based solutions (NBS) · Climate change · Natural hazards · Water resilience

## 1 Introduction

Driven by the prospect of social spaces and economic opportunities, more and more people have been moving into cities over the past century, resulting in urban population increase at a rate faster than ever before. In 1950, urban population accounted for 30% of the world's population; by 2014, this number increased to 54% [37]. As the urban population continues to grow, the urban landscapes become crowded, and the existing civil/municipal infrastructure deteriorates at a faster rate; social and public services are rendered insufficient, and the pressure for quick development rises. In the working group document to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Revi et al. [26] illustrate how expanding urban centers is characterized by dense infrastructure which directly impacts inhabitants' vulnerability to weather disturbances and climate change impacts.

Data projections by the World Health Organization (WHO) indicate a continuous increase in urban population over the next few decades, projecting 2.5 billion people flow by 2050 [37]. This could be inferred as around 6.4 billion people living in cities in the next 30 years resulting in increased demand for food, energy, and water supply. The World Bank anticipates about 50% increase in urban water demands within the next 30 years [31]. Some trends are shown in Fig. 1.

According to a recent estimate, by 2030 (Sustainable Development Goals tenure) close to one billion additional people will live in cities in the Latin America and the Caribbean region which is currently considered the most urbanized developing region globally [35]. The already scarce freshwater supplies and the simultaneous impacts



**Fig. 1** Projected Urban Population by 2050 based on UN World Urbanization Prospects 2018 and others. *Source* ourworldindata.org [27]

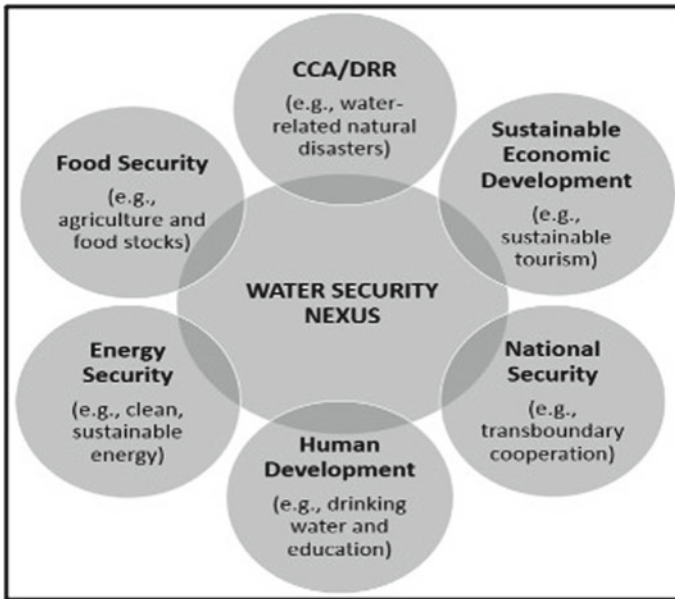
of the water crisis, such as pollution and contamination, call for a paradigm shift to sustainable urban planning, more so in developing cities. This means infrastructure designs of cities must emphasize on community spaces, green zones, and water use–reuse–recycle systems. Moreover, climate change condition exacerbates water insecurity and adds additional need for developing (or adopting) efficient and effective water policies globally. The sustainability issue with the existing (mostly gray) infrastructure and the economic benefits of long-term planning require investigation of nature and resource-efficient solutions that offer multiple benefits to environmental and human health [39].

In this chapter, an overview of the nature-based solutions (NBS) framework is provided within the context of water security and with focus on urban landscapes. Furthermore, gaps and needs are analyzed by quoting examples of best practices worldwide to demonstrate integration of the nature-based solutions in urban planning. We discuss effective and appropriate implementation of NBS toward reducing exposure and vulnerability to urban water insecurity with respect to the Sustainable Development Goals (SDGs) and the New Urban Agenda which together present a foundation for climate and water resilient city planning.

## 2 Overview of Frameworks, Scale, and Sector: NBS and Water Security

A key reference to set the design of this chapter is the water security definition by UN-Water: “*the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability*” [36]. For the first time, this narrative presents water as an interlinked challenge within environmental, social, and political domains. Water security and climate resilience are inseparable, deeply and naturally interconnected [29]. The broad scope of water security framework of UN-Water [36] allows for developing the water security nexus, highlighting the interdependencies between achieving water, energy, and food security with the relational aspects of climate change adaptation (CCA), disaster risk reduction (DRR), and the objectives of human development, national security, and sustainable economic development (Fig. 2).

The integrated water resource management (IWRM) framework introduces three key aspects of *ecological sustainability*, *economic efficiency*, and *social equity* in water management and planning [9]. This framework bears flexibility in context of the larger water security nexus planning and implementation in all settings for urban, agricultural, industrial, and other economic sectors of computing water use; therefore, it has been adopted by many development agencies (including the World Banks and UNDP). IWRM as a water management framework complements the



**Fig. 2** Multiple challenges with relational aspects to the water security nexus (Figure by Tariq Deen)

water security perspective. As such, knowledge and experience between these two conceptual framings can be applied to urban water security agenda setting.

The water security challenges in the urban regions (city, township, or a municipality) are influenced by various drivers such as population density, lifestyle choices, and informal settlements. Climate change impacts on cities manifest in various ways, for instance, increasing heat island effect, dry conditions impacting water availability and recharge, sea-level rise (if that applies in geographical context), coastal or river flooding and erosion, storm surges and stormwater management, flooding, and health outcomes for these impacts noted as heat stress and respiratory disorders [26]. While all urban social groups are either directly or indirectly affected by climate change and environmental stresses, certain groups are more vulnerable; these include the elderly, children, pregnant women, the homeless, people living with disabilities, and people living with low levels of income [39]. Therefore, it is crucial to organize basic water provisioning needs and climate resilience programs for the benefit of all citizens [12].

The urban water security concept finds background in addressing water-related impacts of climate change that threatens cities. Post 2010, some cities have begun to implement strategies to protect their communities, infrastructure, and environmental resources from natural hazards and future impacts of climate change; for example, a public square built in Copenhagen that stores stormwater [20] or the “Sponge City” project constructed in Shenzhen that bears capacity to capture 60% of annual rainfall [5]. Shenzhen aims to minimize the impact of rapid urbanization on the

environment and water pollution to build a sustainable and healthy water circulation system in the future [5]. Nevertheless, implementing such projects often requires an understanding and awareness of ecosystem-based low-impact development (LID) solutions, justification of social and economic co-benefits, governance approach, engagement with multiple actors, and even new financing models [4].

Nature-based solutions (NBS) are initiatives that take advantage of the various mechanisms that nature provides at protecting communities from the destructive forces of natural hazards and other environmental changes. The International Union for Conservation of Nature (IUCN) explains NBS as “*actions to protect, sustainably manage and restore natural or modified ecosystem that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*” [6]. The framework has gained recognition due to the potential it carries to address the emerging challenges of water security and disaster risk management, climate change adaptation, environmental protection, water and human security, and projecting itself as a cost-effective measure compared to traditional hard engineering strategies (see various chapters in Multifunctional Wetlands [21]).

The 2018 UN World Water Development Report highlights the NBS framework as a solution to water crisis, stating that NBS can use or mimic natural processes to enhance water availability (e.g., soil moisture retention, groundwater recharge), improve water quality (e.g., natural and constructed wetlands, riparian buffer strips), and reduce risks associated with water-related disasters and climate change (e.g., floodplain restoration, green roofs). Two significant impacts of climate change on urban areas are reduced water availability (or water scarcity due to dry conditions or water pollution) and rise in unwanted water (flooding). Currently, the solutions to combat these challenges within the urban water management remain heavily dominated by traditional, human-built (‘gray’) infrastructure. The potential for NBS as a means to move beyond existing systems remains underutilized in addressing many of the water challenges, including in the urban settings [39]. The geographical location of an urban population provides some initial considerations for exploring applicable nature-based solutions for urban infrastructure developers. The potential solutions can address three main types of settings representing water security needs in an urban landscape: (a) land-locked urban areas, (b) coastal cities, and (c) watersheds, reservoirs, and other sources of water storage and protection. Some examples are listed in Annexure 1.

NBS systems could be implemented naturally through creation, protection, or restoration of only ecosystem elements. In a joint report, the World Bank Group and World Resources Institute (WRI) propose structural strategies aimed to advance the integration of green and gray infrastructure solutions to substitute, augment, or work in parallel with existing gray infrastructure in a cost-effective manner [4]. Strategizing the NBS approach in urban infrastructure planning aims to find a balance of the green and gray combination that maximizes the benefits and system efficiency of the solutions and minimizes the trade-offs between the costs and the environmental impacts.

A case study example illustrating NBS noted in the Mekong Delta in Vietnam reflects integration of green and gray infrastructure project, wherein mangrove ecosystems were rooted into the project design to restore the existing sea dikes. The rapid aquaculture expansion in late 1980s along the northern coast of Vietnam caused significant loss of mangrove forests that were acting as the area's natural defenses against coastal floods and erosion. To mitigate the impacts of the natural disasters and protect the ever-growing population, restoration of the mangrove forests was agreed as necessary and in 1994, Mangrove Plantation and Disaster Risk Reduction Project was launched to enhance the existing gray infrastructure by investing \$9 million in restoring 9000 hectares (ha) of mangroves area and as 100 km of dike lines by 2010. Noted was significant reduction of maintenance cost of dikes by \$80,000 and \$15 million saved as damage to private property and other public infrastructure also lowered considerably [14]. The coastal cities worldwide are hub of economic activity and therefore to maintain ecological and development balance remain pertinent to ensure sustainable development. It can be argued that often the cost of investment in NBS bears merit in medium to long terms planning, in comparison with short and quick gray infrastructure solutions [24]. In addition, strategies that can combine gray approach and NBS are also investigated by experts and agencies.

NBS is leveraging from existing concepts like the ecosystem-based adaptation (EBA) that propagates well-managed ecosystem as an adaptive tool to climate change and ecosystem-based disaster risk reduction (Eco-DRR) that considers well-managed ecosystem with an objective to reduce the effects of natural hazards that do not necessarily have to be linked to climate change [6]. These two approaches can be used in tandem with NBS to enhance ecological and social resilience, especially in the urban areas with high population density. For instance, mangrove ecosystems have traditionally functioned as a natural strategy for coastal protection because of its complex root structure and dense branch system. Global case studies illustrate how mangroves have helped maintain coastal soil structure and reduce wave energy during storm surges. If planned systematically, mangroves can significantly reduce exposure to coastal hazards like tsunamis and tropical cyclones [11].

Nature-based solutions are widely explored for coastal flooding. Most NBS (or hybrid-NBS) projects reported by the World Bank in 2017 are to combat ongoing river flooding challenges [4]. A good example is river reconnection in China [42]. The construction of dam and dike in the Yangtze River Basin in China from the 1950s to 1970s caused significant undesirable impacts on the existing river-lake wetlands systems. As a result, major flooding events were noted in 1990s that caused loss of life for thousands and direct economic losses in billions of dollars. In a partnership with World Wildlife Fund (WWF), the Chinese Government reconnected the Yangtze River with the disconnected lakes and rehabilitated the natural functions of the wetland system as an attempt to reverse the damages and mitigate the flooding risk. Noted was restoration of nearly 500 km<sup>2</sup> wetlands with floodwater retention capacity up to 300 cubic meter; amid other economic co-benefits of this project and was more than 17% increase in lake districts fisheries production [42].

NBS approach offers variety of co-benefits in tackling challenges related to urban water security and DRR. For example, for tropical regions coastal resilience

strategy, mangrove ecosystems can provide ecological co-benefits in terms of pollution control for aquatic and marine life. Kathiresan and Rajendra [18] show how Indian hamlets with mangroves were significantly less damaged after the 2004 Indian Ocean Tsunami, compared to those without a dense mangrove zone. Das and Vincent [7] observed that mangroves were able to buffer the 1999 super cyclone in Orissa, India. In other parts of the world, the European Union (EU) projects, focusing on efficient and effective design of NBS for restoration of degraded marine environments, demonstrate examples to scale and to support policy negotiations [13].

A common planning challenge for densely populated cities is spatial footage and a lack of available real estate to adopt or implement NBS [24]. Use of integration strategies in existing infrastructure is one of the common strategies in such situations. For instance, roof gardens (also known as living roofs, vegetated roofs, or eco-roofs) address space limitation in densely developed metropolitans. The roofs of buildings can host gardens comprising live vegetation, with innovative structures, built to application; however, the foundation of a layer of soil/growing material and a vapor seal to protect the building from water and vegetation roots are key design aspects, plus additional layers to transport water to a storage tank. These systems are adopted for stormwater management system in some instances, wherein collection of filtered water helps to reduce municipal water demand during dry periods. Around this foundation, construction of hybrid natural solutions plus hard engineering structures to relocate rainwater to storage tanks is an alternative. The stored water can be utilized for provisioning needs such as drinking water during conditions of water shortage. In addition, benefits such as regulation of temperature for the building are noted as the soil layers act as insulators [24]. So, the energy efficiency dimension applies, especially during summer months in buildings and establishments integrating NBS systems as measures for urban planning.

Ho Chi Minh City in Vietnam has a growing population of 8 million. Much of the city's natural landscape is converted to urban expansion and green spaces are limited to 0.25%. The natural drainage system is filled, encroached, or blocked by waste which results in flooding. Upstream development of the Saigon-Dong Nai River results in water shortages for the city during the dry season. The city is exploring options for sustainable urban planning, wherein houses are designed as "pots" with roof gardens to store stormwater and mitigate flooding impacts. A design includes placing a thick layer of soil on roofs to retain stormwater and planting banyan trees to make use of their aerial root system. The ground is made of permeable bricks to increase infiltration during rainfall events. This intervention was tested for the President Place that serves as office and commercial space. Leading to a successful experiment, the building received a Leadership in Energy and Environmental design (LEED) Gold certification in energy and water efficiency category. It used 50% less water than other non-LEED buildings quoted Asian Development Bank [2].

The final case study highlights the importance of policy implication in NBS implementation and developing integrated strategies for NBS deployment [30]. Peru has dealt with water crises related to El Niño for many years; a trend that has been intensified by the climate change effects during last decades. In 2016, the Peruvian lawmakers called the Sanitation Sector Reform Law aiming to remediate the



increasing water-related risks. This policy requires water utilities to earmark revenue from water tariffs for watershed conservation and climate change adaptation and to consider these strategies in the official budgeting and planning processes. The policy was implemented and for 4 years generated \$30 million for NBS via payments for ecosystem services and an additional \$86 million for climate change mitigation and disaster risk management [16].

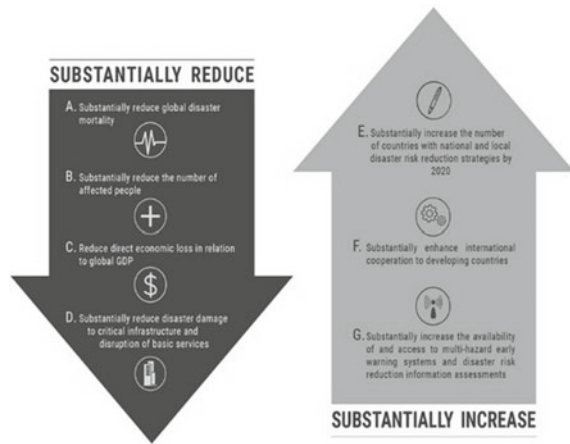
### **3 Global Governance Tools for Sustainability and the Urban Water Security Context**

Sustainable Development Goals (SDGs) are a set of 17 global goals that aim to end poverty, protect the planet, and ensure prosperity for all [41]. The SDGs are the successor to the Millennium Development Goals (2000–2015) and include 169 targets many of which are interlinked. With respect to urban water security, goals 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), 13 (Climate Action), and 15 (Life on Land) contain relative targets for addressing the issue. Some selected examples of SDG targets that apply to urban water security include SDG 6.6 calling for protection and restoration of water-related ecosystems, including mountains, forests, wetland, rivers, aquifers, and lakes; SDG 11.6 emphasizing reduction in the adverse per capita environmental impact of cities, including paying special attention to air quality and waste management. SDG 13.1 on strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries and SDG 15.1 ensuring the conservation, restoration, and sustainable use of terrestrial and inland fresh ecosystems and their services, in particular forests, wetlands, mountains, and drylands, in line with obligations under international agreements.

Water insecurity is an issue that is interconnected with other environmental and socioeconomic challenges, and SDGs provide a guiding framework for cities and communities to identify development priorities with a balanced approach (i.e., human and ecological development agendas addressed in tandem). For instance, SDG targets 6.6, SDG13, and SDG 15.1 all relate to the protection and restoration of aquatic ecosystems, noting that healthy ecosystems are better able to protect communities from climate change impacts and natural hazards and can better serve provisioning needs for people and populations such as drinking water. The concept of resilience is often associated with the defined frameworks, including NBS, steering the notion of creating systems that are better prepared to cope with and recover from natural disasters, environmental changes, and climate change, through the preserving and restoring of basic infrastructure and services. The SDG agenda can only be achieved when its implementation strategies are risk-informed, and water climate and disaster risks are tackled through integrated frameworks. Note that SDG 13.1 calls that countries must plan long-term development tools, rather than responding with short-term emergency measures.



**Fig. 3** Seven goals of the Sendai framework figure. *Source* United Nations Office for Disaster Risk Reduction [38]



The Sendai Framework is the successor to the 2005–2015 Hyogo Framework for Action and was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, in March 2015. This non-binding disaster risk reduction (DRR) agreement asserts that it is the responsibility of the state, local governments, the private sector, and other stakeholders to protect communities against natural hazards. The outcome of the framework states that the substantial reduction of disaster risk and losses in lives, livelihoods, and health in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries covers a period from 2015 to 2030 [40]. The seven goals as summarized in Fig. 3 also link with SDGs to a fair extent.

Other international agreements, like the Paris Agreement, include high-level commitments to promote ecosystem-based solutions such as NBS. The New Urban Agenda [41] describes a vision, with principles and commitments, a call for action, and an implementation plan. It sets the pathway for Sustainable Cities and Human Settlements and is targeted toward the key stakeholders involved in urban governance and planning, including nation states, cities, UN agencies civil societies, and NGOs. The New Urban Agenda also highlights the human right principle and criteria in relation to drinking water and sanitation. Water is embedded within the vision, commitments, and call for action for this agenda offering incentives to design sustainable solutions for urban water management. The frameworks and principles provided assist urban leaders to develop and implement their vision for managing urban water needs and climate resilient cities. Commitments outlined in the New Urban Agenda is provided in Annexure 2. The goal to encourage collaborative action and vision is central to most global governance frameworks so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions on urban water management challenges driven by paradigm shifts [15].

## 4 Key Discussion Points

NBS as a strategy is not to prevent weather disturbances, natural hazards, or environmental processes from occurring but rather to reduce the impact these disturbances have on infrastructure, human lives, and economic activity. Therefore, NBS can and will contribute to the SDG targets and the goals of the Sendai framework in the urban water security context and serve as a strategy to create a frame for policy changes at local government level while allowing focus on resilience in urban planning and infrastructure development.

While there is a growing appetite for investment globally to support nature-based initiatives, there are certain considerations and barriers to implementing NBS projects. NBS planning is often a long-term investment which requires commitments of states and communities through co-creation and consultative processes. In the current system, development priorities do not necessarily align with ecological benefits or inter-agency and regulatory approval processes, lack clarity, or are long and cost intensive. In addition, lack of awareness or shared knowledge about the success stories and best practices serve to limit scalability NBS options [17]. To overcome these underlined challenges, key considerations include careful evaluation, smart planning, minimization of trade-offs in infrastructure planning and participatory approach to project/program design. Some NBS projects are exceedingly context specific and needing customization, as such, technical expertise and systematic analysis on design, planning, and implementation are pertinent. For instance, drought management in urban environments can be challenging since droughts have wide-reaching spatial and temporal impacts including the effect on water availability. Hence, integrated design of a household/residential building to capture rainwater, store access water or recycle–reuse wastewater are options that can be implemented within the NBS framework. Some examples of such interventions are documented in the monograph, Multifunctional Wetlands-Pollution Abatement and Other Ecological Services from Natural and Constructed Wetlands [21].

Other important considerations in implementation of NBS are enabling conditions. Existing practices, programs, and policies need to be modified to allow unlocking NBS opportunities. During past few years, considerable effort toward establishing NBS frameworks is observed. For instance, in 2017 the World Bank outlined eight distinctive steps for planning and strategizing NBS implementation. Building on the work of the EKLIPSE project in the European Union, Raymond et al. [25] developed and proposed a seven-stage process for co-benefit assessment within policy and project implementation for NBS in urban areas. The importance of frequent engagement with stakeholders, continuous monitoring and evaluation post implementation, sharing best practices, and evaluating scaling potential are key dimensions that apply.

International Water Association (IWA) distributed 17 principles for water wise cities toward water sensitive urban infrastructure encouraging policy development at the local scale [15]. The initiative was reassuring for urban developers and decision-makers to share their experience with NBS and encourage mutual partnerships. Such

programs have informed systemic assessment of the values of NBS implementation, commenting that comprehensive evaluation of infrastructure financing and incentives for investing in nature-based infrastructure should be presented clearly to all level of stakeholders. Globally, the urban centers are exploring NBS as alternative based on existing best practices or customizing the framework to fit their settings; ecosystem restoration, wastewater management, water security planning, etc. Overall, NBS is a mixed result story indicating success, but also needs for refinement, possibility for integration with existing infrastructure options, and is an incessantly evolving phenomenon.

Another key aspect to NBS implementation especially for local stakeholders is incentivizing participation. Inclusion of NBS into the municipality codes and regulations is to help accelerate the regulatory and authorization processes, grants, and financial supports for research and related innovation, in particular establishment of financing models to facilitate and promote NBS investments. Green Climate Fund (GCF) is financing mechanisms created under the UN Framework Convention on Climate Change (UNFCCC)—though a handful of NBS projects are funded under this scheme, those focusing to reduce vulnerability and exposure to climate risks are paramount to generate multiple environmental benefits, among other criteria [10]; this could set a good reference for future investments.

## 5 Concluding Notes

Globally, the fast transition into a predominately urban habitation renders urban water security; a major challenge for many countries, particularly for the developing and emerging economies. The urban water management systems can directly impact the socioecological resilience, exposure, and vulnerability of the cities and inhabiting populations. The political stability, geographical location, regulatory norms, and governance techniques are some factors that have role in determining and steering the water secure futures for urban centers. Application of a water security framework to urban design and planning could provide planners, development managers, and decision-makers with an integrated guideline toward effective design solutions, recycle–reuse possibilities, and investment models and policies to address environmental and socioeconomic challenges related to the water sector. Furthermore, the framework can assist to achieve water-related SDGs. Adopting a NBS perspective toward urban water security could also mean tying together political, economic, and social processes toward tackling contemporary suite of challenges in the sustainability, climate change adaptation, and DRR context.

Innovative frameworks such as resilient urban architecture, NBS, and climate sensitive cities are gaining momentum as more urban spaces and communities realize that hard engineering solutions cannot be the only solution as often time those are expensive to construct and difficult to maintain. Comprehensive assessment of initiatives, projects, and programs as explained in this chapter illustrates that investing in NBS is gaining momentum, though NBS is not a “one-size-fit-all” framework. NBS

dimensions pertaining to socioecological and sociocultural settings are deterministic to the limitations and opportunities for this framework to be adopted and scaled for designing water secure cities and communities. The UN Decade on Ecosystem Restoration (2021–2030) with the vision of “*The healthier our ecosystems are, the healthier the planet - and its people*” aims to prevent, halt, and reverse the degradation of ecosystems which globally is expected to boost interest and investment in NBS as a prospective strategy for sustainable urban development [32].

**Conflict of Interest** The authors of this chapter have no conflict of interest to declare.

**Annexure 1. Examples of Different Concepts Related to NBS (Data Source: Thupalli and Deen [33] and World Resource Institute forum on NBS (2018) and World Bank)**

NBS category	Sub-category	Projects	Natural/ecological systems
Urban ecosystem restoration	<ul style="list-style-type: none"> <li>• Ecological restoration</li> <li>• Ecological engineering</li> <li>• Forest landscape restoration</li> </ul>	This approach focuses on the recovery of degraded, damaged/destroyed ecosystem in urban environments. City of Santa Maria in California, USA (Community-Based Restoration Projects supported by NASA)	<ul style="list-style-type: none"> <li>• Riverbeds and banks</li> <li>• Sandy beaches and dunes</li> <li>• Upland forests</li> </ul>
Sector/resource-specific urban ecosystem-related approaches	<ul style="list-style-type: none"> <li>• Ecosystem-based adaptation</li> <li>• Ecosystem-based mitigation</li> <li>• Climate adaptation services</li> <li>• Ecosystem-based disaster risk reduction</li> </ul>	Ecosystem-related approaches vary based on their objective (C.f. [3], Doswald and Osti [8]; Olivier et al. [22])	<ul style="list-style-type: none"> <li>• Floodplains and bypasses or urban flood control</li> <li>• Forest restoration for carbon sequestration</li> <li>• Constructed wetlands</li> <li>• Inland wetlands</li> </ul>
Urban infrastructure-related approaches	<ul style="list-style-type: none"> <li>• Natural infrastructure</li> <li>• Green infrastructure</li> </ul>	Commonly notes in cities (C.f. Ozment et al. [23], Roth [28]) help restore and filter stormwater, avoid cost of stormwater runoff, capture and slow local precipitation, provide energy-saving option for the building	<ul style="list-style-type: none"> <li>• Parks, open spaces, conservation areas</li> <li>• Green roofs</li> <li>• Permeable pavements</li> </ul>

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NBS category	Sub-category	Projects	Natural/ecological systems
Urban ecosystem-based management approaches at large scale and resource governance frameworks	<ul style="list-style-type: none"> <li>• Integrated coastal zone management (ICZM)</li> <li>• Integration water resource management (IWRM)</li> </ul>	IWRM, and ICZM embeds the ecosystem-based management and ecosystem protection aspects of conservation and integrated management (c.f. Arkema et al. [1], Leslie and McLeod [19])	<ul style="list-style-type: none"> <li>• Coastal wetlands</li> <li>• Mangrove forests</li> <li>• Reefs</li> <li>• Salt marches</li> </ul>

## Annexure 2. Commitments Outlined in the New Urban Agenda [34]

Commitment	Description
Providing basic services for all citizens	These services include access to safe and clean drinking water and sanitation
Promoting measures that support cleaner cities	Tackling air pollution in cities by increasing the use of renewable energy, providing greener public transport, and sustainably managing the natural resources
Strengthening resilience in cities to reduce the risk and the impact of disaster	Leaders have now committed to implement mitigation and adaptation measures to minimize the impacts of natural disasters. These measures include urban planning, quality infrastructure, and improving local responses for safety and environmental sustainability
Taking action to address climate change by reducing greenhouse gas emissions	Sustainable cities that reduce emissions from energy and build resilience can play a lead role. Leaders committed to involve with local governments and all actors of society to take climate change action and considering the Paris Agreement on climate change
Improving connectivity and support innovative and green initiatives	This includes establishing partnerships with businesses and civil society to find sustainable solutions to urban water challenges in case of flooding or any other risk disaster

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Commitment	Description
Promoting safe, accessible, and green public space	Sustainable urban design plays a key role in ensuring the livability and prosperity of a city. The agenda calls for an increase in public spaces to facilitate human interaction by urban planning

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