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Review

Implementation of Nature-Based Solutions in Urban Water Management in Viet Nam, a Comparison among European and Asian Countries

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Abstract: Climate change is severely affecting all regions of the world, and urban water management has become a major urban challenge. Although nature-based solutions (NBSs) have been widely implemented in developed countries in the Global North to address stormwater-related challenges in urban areas, implementation of such approaches in Viet Nam and other Asian countries remains limited. In addition, comprehensive and critical reviews of NBS adoption and development processes in Viet Nam are scarce. This study aims to clarify several aspects through a literature-based review: to understand the development of urban water management in Europe and Asia (China and Southeast Asian countries) along with the drivers for NBS implementation in Viet Nam, to explain the barriers to NBS adoption in Viet Nam, to present feasible solutions for promoting NBS adoption, and to explore future perspectives for NBS development in the context of Viet Nam. Although significant barriers exist, opportunities for NBS implementation are evident. The findings of this study can be used to promote NBS in other municipalities in developing countries.

Keywords: nature-based solutions; blue–green infrastructure; sponge city; sustainable urban planning; environmental policies; implementation challenges; transnational collaboration; climate change adaptation; literature review; urban water management

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1. Introduction

Climate change is ubiquitous and severely impacts people, the environment, and the economy each year. Without adaptation, the number of people who may lack sufficient water availability, at least one month per year, will increase from 3.6 billion today to more than 5 billion by 2050 [1]. Furthermore, growing trends of sea level rise and greater storm surges could result in a total cost to coastal urban areas of more than USD 1 trillion each year by 2050. As climate change increasingly affects lives and livelihoods, maximizing adaptation opportunities will minimize its potential impacts.

As the global population has increasingly concentrated in cities and climate has continued to change in ways that have potentially severe impacts on urban populations and infrastructure, cities occupy a dominant position in the adaptation agenda [2,3]. To date, there are numerous engineered solutions for managing climate-change-related risks and natural disasters, including sea walls, levees, pipes, and irrigation infrastructure [4]. However, these traditional infrastructure systems often route runoff to sewer networks during heavy rainfall or directly to streams and rivers, intensifying pollutant loads and hydrological disturbance (groundwater recharge and evapotranspiration). This, in turn, contributes to degradation of the ecosystem's structure and function [5]. Researchers and practitioners have supported a new response to climate change mitigation and adaptation, which has the potential to be more effective and sustainable than traditional approaches. This approach is currently known as nature-based solutions (NBSs) [6,7]. The concept of NBSs emerged in the 2000s to promote nature in addressing the challenges associated with climate change. NBSs are solutions which utilize or are inspired by nature to address major global challenges, including, but not limited to, climate change, food security, and social and economic development [8]. This concept is increasingly being developed and applied by the International Union for Conservation of Nature (IUCN) and other organizations such as the European Commission (EC). In contrast to the abundance of engineered solutions, such as dams, levees, reservoirs, treatment systems, and pipes, NBSs have the potential to confront both climate change mitigation and adaptation challenges at a lower cost while bringing multiple benefits for people and nature [9]. NBSs can be more cost-effective than engineered solutions, such as seawalls, and the use of both in combination should be encouraged, as NBSs can improve the performance of grey infrastructures [1,10].

Generally, NBSs can be categorized into sectors and thematic areas of social significance. These include water management, forests and forestry, agriculture, and urban and coastal areas [11,12]. In this study, we focus on the urban water management sector. NBSs for urban stormwater management aim to control surface runoff volumes and timing, and thus reduce the risk of flooding during heavy rainfall events. They help convert the linear approach of conventional stormwater management into a more cyclic approach that mimics the natural water flow [13]. Despite the greater vulnerability of developing countries and communities in the Global South to climate impacts, most research on NBSs has focused on Europe and other regions in the Global North, with limited evidence on NBS practices available in the Global South [6,7,14].

Looking back at the evolution of urban stormwater management, most existing stormwater infrastructure in developed cities has primarily relied on sewer systems developed in the second half of the 19th century in Europe [15]. Initially designed exclusively for flood control, these systems have evolved over the past fifty years to incorporate more diverse and integrated approaches adapted to various local contexts and include an increasing integration of objectives, disciplinary, functionalities, and social and cultural demands [15,16]. Despite the availability of various sustainable urban water management approaches worldwide, many secondary and tertiary cities in Southeast Asia (SEA)—such as those in Laos, Cambodia, Indonesia, Thailand, and Viet Nam—still face significant infrastructure gaps and implementation challenges. These cities are struggling with issues like water scarcity, flooding, untreated wastewater, and inadequate sanitation. While there were notable improvements in urban water management across the region between 1990 and 2015, untreated wastewater is still often discharged directly into stormwater drains and rivers, particularly during heavy rainfall events [17].

Viet Nam, situated in Southeast Asia and bordered by the Pacific Ocean, covers a total land area of 331,235.97 km^2 and has a coastline stretching 3260 km. The country's extensive coastline makes it particularly vulnerable to climate change impacts, such as sea level rise, and it ranked 13th in the 2019 Global Climate Risk Index [18]. The climate extremes in Viet Nam were recorded at higher intensities and frequencies. Between 1958 and 2018, the country's average yearly temperature increased by approximately 0.89 °C, and annual precipitation increased by 2.1%, with the highest observable increase on the south central coast [19]. In developing countries such as Viet Nam, most urban areas have experienced high population density and continued rapid urbanization, with sealed surfaces and densely compacted soil replacing the naturally permeable landscape. As a result, such urban areas have frequently witnessed severe urban flooding due to overloading of drainage systems. This problem will be exacerbated through an increasing number of extreme events caused by changing climatic conditions [20].

To date, the Vietnamese government has put in place several key climate-change-related decisions, including the landmark Plan for Implementation of the Paris Agreement in 2016, and submitted its revised National Determined Contribution (NDC) report in September 2020. Climate change in Viet Nam has maintained the trends identified in the NDC as related sectors, regions, communities, and infrastructure have continued to face increasing risks and potential impacts of changing climate. Droughts and floods have affected the urban water supply system, whereas its adaptive capacity to climate change impacts is only at a medium or low level [19]. As identified in the updated NDC report, adaptation measures, including NBSs, should be implemented in the future to minimize the damage associated with climatic change in each sector. However, current adaptation measures mostly focus on engineered measures, whereas NBSs have not received adequate attention.

While some Vietnamese legal documents have mentioned climate change adaptation and NBSs, there is a lack of comprehensive understanding regarding the implementation and development of NBSs in the country. In addition, comprehensive and critical reviews of NBS adoption and development processes in Viet Nam are scarce. This study aims to clarify some aspects through a literature review to (1) understand the development of urban water management in Europe and Asia (China and Southeast Asian countries), as well as the drivers for NBS implementation in Viet Nam, (2) explain the barriers to NBS adoption in Viet Nam, (3) illustrate feasible solutions for NBS adoption, and (4) explore future perspectives of NBS development based on Viet Nam's context. This study contributes to a better understanding of NBS approaches and benefits, as well as the promotion of NBS implementation in Viet Nam and municipalities in other developing countries.

2. Development of the Nature-Based Solutions Concept

The term "nature-based solutions" (NBSs) was first introduced in the 2000s to address climate change impacts. The IUCN began using this term to describe strategies that utilize natural processes and ecosystems to provide sustainable and cost-effective solutions to various environmental and social challenges [15,21,22]. The World Bank (WB) used the NBS concept to highlight the importance of biodiversity conservation for climate change mitigation and adaptation in its report on "Biodiversity, Climate Change and Adaptation: NBSs from the World Bank Portfolio" which was published in 2008 [23]. In 2012, the IUCN first formulated a formal definition of NBSs. Subsequently, the term NBS was supported and broadened by the IUCN and EC [21,24–26] and is widely used in the literature as a method for enhancing resilience to climate change impacts. The EC has developed an EU Research and Innovation (R&I) agenda on NBSs in its Horizon 2020 Framework Program [25,27] and has continued to address NBSs in its Green Deal Calls and Horizon Europe Calls. In 2020, the IUCN published the Global Standard for NBS to provide guidance and a framework for the design, verification, and scaling up of NBSs [28]. The development of the NBS concept is summarized in Figure 1.

There are some differences in the definition of NBSs between the IUCN and the EC. As defined by the IUCN, NBSs are "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" [24]. Meanwhile, EC recognizes NBSs as "solutions to societal challenges that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits, and help build resilience". Such solutions bring diverse natural features and processes into cities, landscapes, and seascapes through locally adapted, resource-efficient, and systemic interventions [11]. The IUCN defined NBSs as "actions" and suggested that the fundamental approach of NBSs is to actively apply sustainable management and conservation of natural resources to tackle various societal challenges, such as climate change, food security, water security, and natural hazards [29,30]. From the EC's perspective, NBSs are described as "solutions" aimed at helping society, meeting various environmental, social, and economic challenges in a sustainable manner, and these solutions are inspired and supported by nature or copied from nature [31]. For comparison, the definition of the EC is somewhat broader because it considers cost-effectiveness and resource-use efficiency, which were not mentioned in the IUCN definition. However, both definitions cover aspects similar to living solutions or actions that promote nature to bring multiple benefits and address multiple societal challenges.

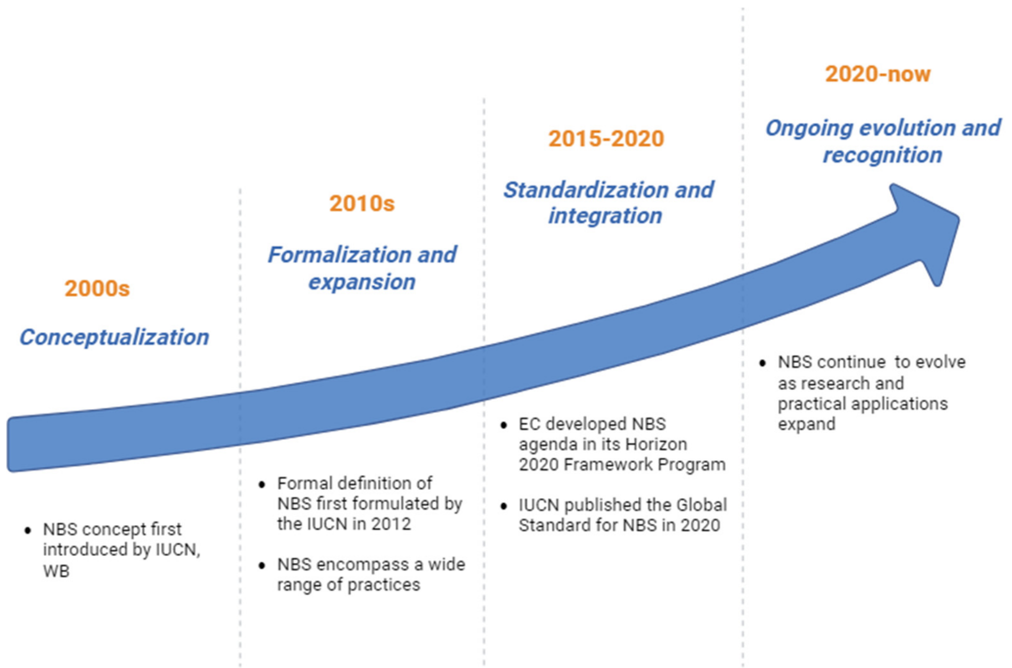

Figure 1. Summary of the development of NBS terminology [8,21–28].

During rainfall on natural, undeveloped land, rainwater slowly drips off the canopies of the trees and runs through the foliage at ground level to natural water storage areas, such as ponds, marshes, and puddles. In this way, stormwater is naturally managed through infiltration and evapotranspiration. With the progress of urbanization, natural land cover has been replaced with impervious surfaces such as roofs, streets, sidewalks, and parking lots, which cannot slow down water velocity or allow them to infiltrate, leading to increased surface runoff and flooding in urban areas [32].

In addition, changing climate is expected to alter rainfall patterns, leading to an increase in the number and magnitude of extreme rainfall events and frequent overloading of drainage systems [20], which requires increasing nature-based interventions in stormwater systems to increase the adaptive capacity to climate change [3,33]. Green infrastructure plays an important role in cities' resilience to extreme stormwater events associated with changing climatic conditions and can provide the capacity to effectively reduce peak flow rates and runoff volumes and remove pollutants from stormwater, such as total suspended solids (TSSs), heavy metals, total phosphorus (TP), and total nitrogen (TN) [34,35]. NBSs such as green roofs, stormwater ponds, bioswales, raingardens, and retention basins can store and promote infiltration and evaporation of stormwater [3], offering higher adaptability than centralized drainage systems, especially in view of the uncertainties associated with climate change [36,37].

Fletcher et al. [16] suggested a possible classification of urban drainage terminology that has been widely used in recent decades, such as best management practices (BMPs), sustainable urban drainage systems (SUDSs), low-impact development (LID), water-sensitive urban design (WSUD), integrated urban water management (IUWM), and green infrastructure (GI). Some terms primarily focus on the entire urban water cycle management (i.e., IUWM, WSUD, GI, LID), while others focus on urban stormwater management (i.e., BMPs, SUDS). The SUDS is a type of NBS that copies nature, managing stormwater runoff and providing multiple benefits to urban areas. It is recognized as one of the main NBS techniques to improve urban stormwater management in the context of climate change [38]. Although some parties neglect "urban" from the term, mentioning them as sustainable drainage systems (SuDSs), their meaning is fundamentally the same. This change may reflect an aspiration to consider both rural and urban land use [16]. Examples include rainwater harvesting systems, green roofs, pervious pavement, bioretention systems, trees, swales, detention basins, retention ponds and wetlands, soakaways, and infiltration basins. These solutions can help to harvest, infiltrate, slow, store, convey, and treat runoff [39]. The SUDS has been widely applied according to available data for implementation and case studies in developed countries such as the United States, Australia, and Europe [6,12,24]. In China, stormwater management facilities have not kept pace with rapid urban development. Drainage systems are often insufficient or poorly maintained, failing to meet the needs of growing urban populations and changing climate conditions. Pluvial flooding has become more frequent and severe in many Chinese cities in recent years [40]. Sponge city (SC), a term coined in 2013, refers to the GI's ability to absorb and release water like a sponge, aiming to manage urban flooding, purify stormwater, and create opportunities for water reuse [41,42]. A sponge city is a decentralized solution similar to LID, but has three distinctive features: its large-scale implementation, multiple objectives, and a unique funding structure [43]. Since the launch of the Sponge City Program (SCP) in 2014, China has taken significant steps to address water-related challenges, aiming to tackle urban flooding while promoting sustainable urban development and reducing environmental impacts [40,44].

There are numerous relevant terms for NBSs that vary by region or sector [16,45]. During the early 2000s, "green infrastructure" (GI) was introduced across Western countries by merging "best management practice" (BMP) and "low-impact development" (LID) principles. This approach aims to effectively handle stormwater while simultaneously enhancing environmental, social, and economic sustainability [46]. Blue–green infrastructure (BGI), as an umbrella notion, is closely related to the concept of "green infrastructure"—where blue (water) and green (vegetation) elements are integrated, creating a multifunctional impact in urban spaces [47]. A bibliometric review of disciplinary variation in the definitions of GI conducted by Matsler et al. [45] showed that the nature-based solutions term is the most frequently used term in Europe, with the majority of publications deriving from Italy, the UK, and Sweden. European scholars also dominate the BGI concept, whereas the sponge city term originated in Asia. This is proven by the evidence that 75% of all sponge city papers are authored by Chinese researchers [45].

In this work, we focus on three terms: "nature-based solutions" (NBSs), "blue–green infrastructure" (BGI) and "sponge city" (SC). Although the boundaries between these concepts (NBS, BGI, and SC) are blurred, they share several similarities, such as a consensus on the protection of natural ecological systems and a focus on economic, social, and environmental advantages. Nevertheless, there are also some differences: (i) although BGI is the most established and closely related concept to NBSs, it primarily concentrates on applications in urban areas; (ii) SC is an ecological rainwater management concept based on LID. SC has strong short-term targeting and significant effects, whereas NBSs offer a more comprehensive cost–benefit approach that spans over the entire lifecycle [42].

3. Methodology

To conduct a wider review of NBS approaches in urban water management in Viet Nam, other Southeast Asian countries, Europe, and China, further overlapping terminologies that meet the NBS concept, such as BGI and SC, were searched in this study. The keywords used in this research were: "nature-based solutions", "sponge city", and "blue-green infrastructure". The sets were sequentially searched in "Web of Science" (https://www.webofscience.com/wos/woscc/basic-search, accessed on 12 December 2023) by searching the "All fields" scope using the Boolean operator "AND" among three above keywords with "urban water": "nature-based solutions" AND "urban water", "sponge city" AND "urban water", "blue-green infrastructure" AND "urban water". Focusing on urban water in European countries, China, and Southeast Asia, we excluded publications from other countries by using the refine tool "Countries/Regions" in "Web of Science". We also searched for the three pairs of keywords mentioned above for the country (Viet Nam/Vietnam). A total of 250 articles were retrieved and revised. Emerging duplications were manually removed using a Microsoft Excel file, where titles were filtered.

After excluding duplicates, 232 studies remained. Some criteria were then defined to narrow down the information, as outlined below: (1) source type: only peer-reviewed journals were considered for inclusion; and (2) language: only articles written in English were included in the study.

In terms of eligibility criteria, articles providing relevant information of urban water management practices, regarding challenges and opportunities, ecological services, water balances, climate changes, runoff, and design criteria at all scales (building, district, or city), were included in the analysis. This screening yielded 58 publications that were included in the full review. A list of papers can be found in the Supplementary Materials (Table S1). The review methodology is illustrated in Figure 2.

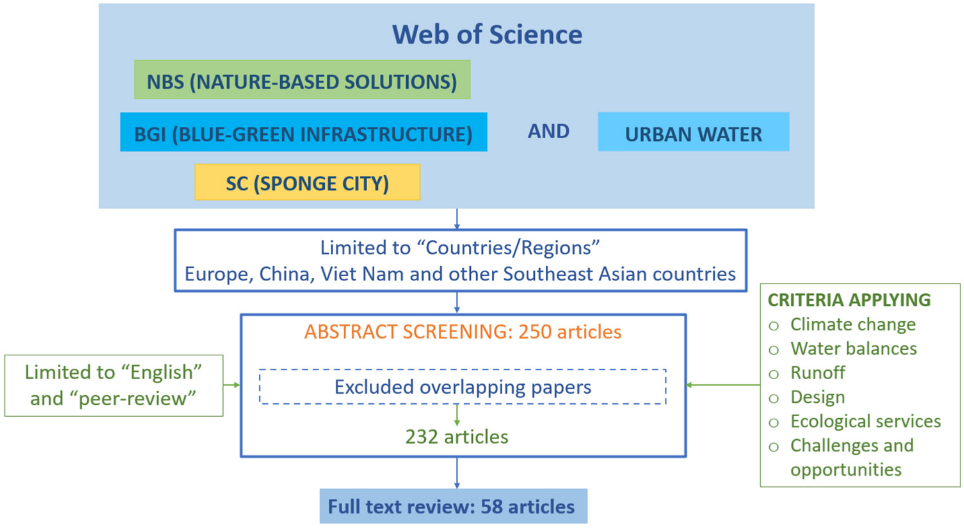

Figure 2. Literature review approach.

This systematic review of the existing literature was conducted following the PRISMA workflow [48]. In addition to 58 publications resulting from the systematic review, we also examined grey literature (5 records), including reports and policy documents published by multilateral organizations and the government of Viet Nam to better understand the current status of NBS implementation in the country.

4. Results

The numbers of studies included in this work, identified through the search and selection process, are presented in the Supplementary Materials (Table S2). The focus of this study is the implementation of NBSs in Viet Nam in the field of urban water management, while conducting a comparison with European and Southeast Asian countries and China. The findings are defined in the following three points: (1) development and distribution of NBS research, (2) current progress of urban water management, and (3) barriers for NBS implementation in these regions.

4.1. Development and Distribution of NBS Research over the Regions

The number of papers regarding NBS research in urban water areas has been increasing over the years, as shown in Figure 3. Among the fifty-eight analyzed publications, China is the leading country with twenty-nine articles, followed by European countries with thirteen articles, whereas only one article is from Viet Nam, three from Southeast Asia, one from both Europe and Southeast Asia (case studies were conducted in Portugal and Singapore), and one from both Europe (the United Kingdom) and China.

The distribution of publications by region and country is shown in Figure 4 and in Table S1 in the Supplementary Materials. The results indicate that there are limited studies on NBSs in the urban water field in Viet Nam as well as in other Southeast Asian countries.

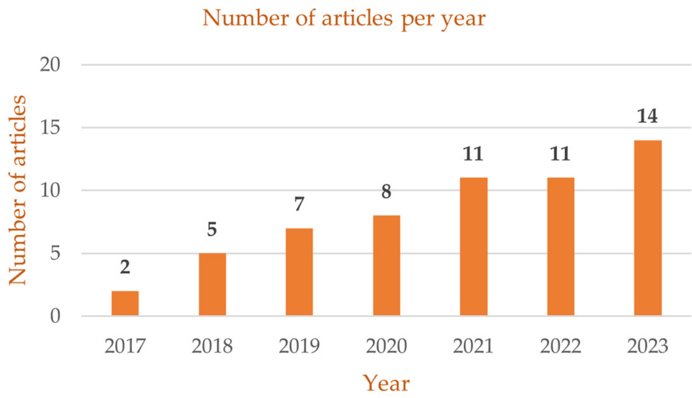

Figure 3. Increasing number of articles in NBSs in urban water areas over the years.

Figure 4. Distribution of articles per region and country.

4.2. Categorization of Research Types

We categorized the 58 articles into five research content types, as shown in Table 1. The numbers of articles and typical publications based on the content type are also shown in this table. The detailed categorization of all articles can be found in the Supplementary Materials (Table S1). It should be noted that the review of NBS concepts, measures, technologies, barriers, and opportunities in terms of ecological services, climate changes, water balance, runoff, modeling, planning and optimization of urban water systems, and evaluation of NBS practices' performance through case studies are key research directions of NBS studies, accounting for 97% of our analyzed articles. The remaining 3% relates to policy and implementation experiences and classification of NBS practices.

Table 1. Categorization of the research articles into content types.

Content Type	Number of Papers	Description	Typical Literature
Content #1	21	Review of NBS concepts, measures, technologies, barriers, and opportunities in terms of ecological services/climate changes/water balances/runoff	Lechner et al. [49]; Zevenbergen et al. [44]; Bąk and Barjenbruch [50]; Xia et al. [51]; Zha et al. [52]
Content #2	25	Modeling, planning, or optimization of urban water system	Li et al. [53]; Khurelbaatar et al. [54]; He et al. [55]; Yang et al. [56]; Jiang et al. [57]
Content #3	10	Evaluation of NBS practices' performance through case studies	Gonzalez-Flo et al. [58]; Song et al. [59]; Liu and Jensen [13]; Yang et al. [60]; Richter and Dickhaut [61]
Content #4	1	Policy and implementation experiences in construction and financing	Zhou et al. [43]
Content #5	1	Classification of NBS (green roof) practices	Snep et al. [62]

4.3. Current Progress of Urban Water Management in Europe, Asian Countries, and Viet Nam

4.3.1. In European Countries

The NBS approach in managing urban water is currently more widely employed in Europe than Southeast Asian and developing countries, as evidenced by various studies and projects [47,50,58,61,63–66]. For instance, three BGI projects at Potsdamer Platz and Block 6 in Berlin and Bosco Verticale in Milan [47] showed that these initiatives can effectively respond to extreme weather events by mitigating the consequences of heavy rainfall and prolonged drought, while also improving the microclimate. According to Bąk and Barjenbruch [50], rain gardens are important solutions in BGI, mainly due to their ease of implementation and relatively low costs. In addition, an analysis by Chen and Gaspari [66] indicated that rain gardens, permeable pavements, and infiltration basins are highly effective for managing rainwater runoff at the district scale, while green roofs are a particularly effective solution as they offer multiple benefits at the building scale. The effectiveness of green roof systems in reducing flood risks from heavy rainfall, increasing evaporative cooling, and biodiversity has also been proven by a long-term monitoring study in Hamburg [61]. Gonzalez-Flo et al. [58] evaluated the 20-year performance of a constructed wetland combined with a reclamation plant in Can Cabanyes Park, Spain, and found that it demonstrated excellent water quality, making it highly suitable for water reuse practices. The city of Belgrade, Serbia, has planned several green infrastructure designs through NBSs to address multiple climate- and urbanization-related challenges, taking into account the positive impacts on ecosystems [65].

Urban water management in the last few decades has focused on reducing floods; however, other objectives also need to be met to improve water quality, recycle rainwater, enhance biodiversity, provide amenities, and reduce urban overheating [15,63,66].

4.3.2. NBS Uptake in Asian Countries and Viet Nam

According to Zevenbergen et al. [44] and Lashford et al. [67], the Chinese government proposed the concept of sponge cities in 2013, and the Sponge City Program (SCP) was officially launched in 2014 with direct guidance and support from the Ministry of Housing and Urban-Rural Development (MOHURD), the Ministry of Finance (MOF), and the Ministry of Water Resources (MOWR). The SCP aims to implement nature-based solutions to tackle urban water-related challenges with the key goals of waterlogging and flood mitigation, water quality enhancement, rainwater reuse, and microclimate improvement. In November 2014, the MOHURD issued the Sponge City Development Technical Guideline: Low Impact Development [68]. It can be seen that the concept of the SC was initially associated with low-impact development (LID). Since their introduction to the public, the number of studies on SC has rapidly increased. Our review also reflects this trend, as shown in Figures 3 and 4. The research has focused on the implementation, planning, and optimization of SC measures, as shown in different case studies [69–73].

The SCP has proven to be highly beneficial for improving urban resilience in regard to runoff volume reduction, water quality enhancement, and urban ecosystem improvement [59,72,74,75]. This initiative tested 30 pilot cities across the country in 2015 and 2016, encompassing diverse climatic, hydrological, and geographical conditions [43]. All these cities completed performance assessments by the end of 2019 [76]. These pilot projects have passed the joint check by the MOHURD, the MOF, and the MOWR on performance evaluation in terms of water environment, water resources, water security, and water ecology. Building on the experiences of pilot cities, China began to systematically promote sponge city demonstrations on a national scale [68]. However, the SCP has encountered a variety of challenges, including technical and physical constraints, financial obstacles, administrative issues, and challenges related to public awareness and acceptance.

Recently, several NBS projects have been implemented in Southeast Asia. For instance, in Singapore, the Active, Beautiful, Clean Waters (ABC Waters) Program for flood control was launched by the Public Utilities Board (PUB) in 2006, and then 75 projects were implemented under this program between 2010 and 2018 [64]. The ABC Waters Program aims to integrate a water-sensitive urban design approach into the water infrastructure, landscapes, and buildings. With the sponsorship of the Asian Development Bank (ADB), water-sensitive urban design (WSUD) was implemented in several pilot provinces and cities in Viet Nam (Vinh Yen, Hue, Ha Giang, and Ho Chi Minh City). The objective of this project was to integrate NBSs through the rehabilitation of ponds, parks, and rivers in these cities to enhance their sustainability and climate resilience [77]. However, compared to other regions, there is relatively limited literature on the application of NBSs in Southeast Asia [49]. In this study, we only identified four papers on the implementation of urban water management in this region, with one study specifically focusing on Viet Nam.

To better analyze the current progress of urban water management in Viet Nam, we also reviewed reports from international organizations (e.g., UNCC, UNDP, WB, and ADB), policy documents, and national reports from the Government of Viet Nam (GOV). A Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) by the Intergovernmental Panel on Climate Change (IPCC) in 2015 [78] recommended various measures to enhance the management of climate and disaster risks in Viet Nam. It emphasizes the benefits of ecosystem-based solutions and complementary climate risk transfer mechanisms, such as climate risk insurance solutions. The GOV submitted its revised National Determined Contribution (NDS) report in September, 2020 [79]. As mentioned in the updated report, adaptation measures, including NBSs, should be adopted to reduce damage associated with climate change across various sectors. In 2022, the National Adaptation Plan (NAP) for the period 2021–2030, with a vision for 2050, was developed based on the guidelines of the United Nations Framework Convention on Climate Change (UNFCCC). The NAP comprises detailed and specific solutions deployed in the medium- and long-term to mitigate vulnerability and risks induced by climate extremes [80]. However, current adaptation solutions for urban water management predominantly focus on engineered measures, whereas NBSs have received insufficient attention. Additionally, the lack of literature and data in this field makes it challenging to thoroughly analyze the current status of NBS implementation in Viet Nam.

4.4. The Barriers on Implementing NBS in Southeast Asia and Viet Nam

First, the urbanization features of Southeast Asian countries differ from those of most countries in the Global North. Lechner et al. [49] highlighted that the extremely high density of Asian cities has put significant pressure on blue–green infrastructure to deliver benefits. Cities such as Bangkok, Jakarta, and Manila are distinctive because of their high population densities and large total populations [49,81]. Second, the climatic context in this region, with tropical rainforests and tropical monsoons, is hot and humid, with high annual precipitation and frequent intense weather events. Viet Nam has a tropical monsoon climate, with the annual average rainfall varying sharply across regions, ranging from 600 mm to 5000 mm, most commonly between 1400 mm and 2400 mm [82]. Cities in such regions are increasingly susceptible to urban flooding owing to extreme rainfall events. Third, technical difficulties and funding challenges for NBSs include the lack of an appropriate simulation model that includes the relevant factors based on evidence for implementing NBS designs. There is also a lack of funding for the Southeast Asian region [49]. For instance, there are only a few recent projects sponsored by the Asian Development Bank (ADB), and water-sensitive urban design (WSUD) has been mainstreamed into several pilot provinces and cities in Viet Nam. Budget constraints are also a significant barrier to NBS implementation in this region [77].

5. Discussion

5.1. Drivers for NBS Implementation in Viet Nam

NBS projects are driven by at least one of the following factors: climate resilience and adaptation, sanitation and waste management, income and food security, and cultural and recreational benefits. Given the country's context, governance and economic factors are the primary drivers of most decisions in development planning and the implementation of NBSs for climate resilience and adaptation.

Currently, roles and responsibilities among ministries, sectors, and provinces in implementing climate change adaptation activities have been clearly defined in the GOV's policy documents; however, coordination among relevant ministries, sectors, and local authorities remains insufficient [80]. Collaboration among governmental agencies at all levels is limited in integrating, evaluating, and scaling up climate change adaptation models across regions. For example, in Viet Nam, the Ministry of Natural Resources and Environment (MONRE) plays a leading role for climate-change-related issues. While the MONRE has issued development plans for the fields under its management scope and climate change adaptation is integrated at different levels, the Ministry of Agriculture and Rural Development (MARD) has issued a Directive on the formulation of the five-year agricultural and rural development plan for the period 2021–2025 which also included climate change resilience issues [80].

In the SCP, the Chinese central government carries the main responsibility and plays a leading role in the formulation of planning ideas and selecting development directions for promoting SC construction. The roles and responsibilities of key stakeholders, including governmental institutions, communities, and private sectors, are clearly identified [42,76,83]. The governance of the SCP is characterized by a top-down approach, involving shared administration among governmental agencies at different levels. As a one-party state, similar to China, Viet Nam's central government has played a pivotal role in formulating and implementing environmental and climate strategies and initiatives on green growth. In highly centralized authoritarian states that govern through one-party rule like China and Viet Nam, formal political institutions can mitigate some of the difficulties associated with authoritarian power sharing [84]. The governance in the SCP in China can serve as valuable reference for Viet Nam to promote NBS projects.

Due to the lack of literature and data on NBS implementation in Viet Nam, costs of NBS measures based on case studies from Europe and China are discussed in this section. This aims to provide Vietnamese decisionmakers and researchers with an overview of NBS implementation costs, enabling them to consider cost-effective solutions that also deliver environmental benefits.

Biasin et al. [85] have identified costs (implementation and maintenance costs) and scored performance effectiveness of 15 NBSs against flood risk mitigation, heat island effect reduction, and environmental benefits. The assessment of NBS performance was conducted based on the Natural Water Retention Measures (NWRM) initiative, in which each NBS measure was assigned a score ranging from 0 (no impact) to 3 (high impact). Environmental co-benefits, such as biodiversity conservation and recreational opportunities, were assessed using the same approach. Table 2 shows costs and performance valuation of 10 NBSs, ranked from the lowest to the highest installation cost. In comparison with other regions around the world, the costs of input factors for NBS projects in Europe are relatively high, particularly for labor and land. A higher level of impact could be generated for the same level of investment in other regions outside Europe [86]. Investing in NBS projects in areas outside of Europe, for instance, in Southeast Asian countries where input costs are lower, could have the potential for greater impacts.

The statistical results of SC type distribution regarding urban runoff source control facilities (URSCFs) in 30 pilot sponge cities [87] indicate that bioretention, permeable pavement, detention cells, grassed swales, and constructed wetland are the top five most implemented facilities in China. Due to the limited availability of operation and maintenance cost data, Xu et al. [87] only presented the construction costs of these facilities, as described in Table 3. The variation range of facility costs in construction projects is primarily influenced by variations in material cost, labor cost, and design parameters of facilities across different regions.

Table 2. Costs and performance valuation of several NBS measures in Europe, adapted from [85].

No.	Measures	Costs		Performance Valuation of NBS	
		Installation (EUR/m^2)	Maintenance (EUR/m^2)	Effectiveness against Flood Risks	Environmental Co-Benefits
1	Rain gardens	1.08	0.3	1.6	1.7
2	Forested green areas	1.32	2.49	1.9	2.3
3	Urban gardens	3.85	3.85	1.2	1.6
4	Retention ponds	14	3	1.6	2.1
5	Infiltration basins	26.25	2.83	1.6	2
6	Rainwater harvesting	32.5	0.63	0.1	0.5
7	Roadside trees and green paths	33.78	34.22	1.6	2.2
8	Permeable surfaces	65	3	0.7	0.7
9	Green roofs	77.5	55	1	1
10	Infiltration trenches	80	2.12	1	1.2

Table 3. Construction costs of URSCFs in 30 pilot sponge cities in China, adapted from [87].

No.	Facility Types	Construction Costs			
		Average (CNY/m^2)	Average (EUR/m^2) *	Reference Value (CNY/m^2)	Reference Value (EUR/m^2) *
1	Grassed swale	234.4	29.67	-	-
2	Permeable pavement	329.51	41.71	60–200	7.59–25.32
3	Wet pond	366.67	46.41	400–600	50.63–75.95
4	Bioretention	402.49	50.95	150–800	18.99–101.27
5	Green roof	539.8	68.33	100–300	12.66–37.97
6	Constructed wetland	762.5	96.52	500–700	63.29–88.61
7	Infiltration trench	772.5	97.78	-	-
8	Dry pond	1000	126.58	-	-
9	Detention cell	1611.11	203.94	-	-
10	Rain harvesting system	3166.67	400.84	-	-

* EUR 1~CNY 7.90 (European Central Bank exchange rates, https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/index.en.html, accessed on 18 September 2024). The Sponge City Construction Technical Guide by MOHURD (2014) serves as the source for the reference values presented in the table.

5.2. Future Perspectives of NBS Development in Viet Nam

Viet Nam is facing challenges similar to those in the tropical Southern China region, therefore, lessons and experiences gained from the SCP could serve as valuable guidance for promoting NBSs in the country. For example, Shenzhen and Zhuhai are classified as large and medium cities, respectively, and both have humid climates with average annual rainfall exceeding 1800 mm [68,88]. These pilot sponge cities have implemented measures that integrate grey and green infrastructures to enhance water ecology (total annual runoff volume capture rate), water security (flood control), water environment (source pollution control), and water resources (rainwater resource utilization) [68]. Given their similar urban characteristics and climatic conditions, these cities can serve as demonstration cases for cities in Viet Nam.

NBSs or green infrastructure can improve urban resilience by mitigating flooding, enhancing water quality, creating opportunities for water reuse, providing amenities, and improving microclimates [15,58,61,63,65,66]. Green infrastructure can alleviate pressure on traditional grey infrastructure, however, during extreme storm events, traditional grey infrastructures are still an essential part in SC construction when considering safety. Small-scale NBS infrastructures are only effective for rainfall events with low return periods. For effective mitigation of urban flooding, large-scale NBS infrastructures, in combination with conventional grey infrastructures, are necessary [7]. Integrating green and grey infrastructures can provide a more robust solution for urban water system management [76], although the combined approach of green and grey assets has not gained popularity [42]. In addition, such a coupled approach can help to mitigate or offset the ecological negativity of grey infrastructure while reducing the economic uncertainties associated with merely green solutions [89].

Undoubtedly, there is substantial potential for capacity building in the country through the establishment of partnerships with nations that have proven records in effectively implementing NBSs, such as China and European countries. This involves facilitating innovative knowledge sharing through collaborative research projects. Under numerous NBS projects sponsored by the European Commission, various dialogue platforms to promote innovation with NBSs have been established, for instance, Climate-ADAPT [90], Oppla [91], NetworkNature [92], ThinkNature [93], and Urban Nature Atlas [94]. Key features and links to the webpages of these platforms are presented in Table 4. Such open assessment databases can facilitate the widespread adoption of NBSs by fostering knowledge sharing, collaboration, policy development, public engagement, and innovation.

Table 4. EU dialogue platforms for NBS promotion.

Projects	Key Features	Websites
Climate-ADAPT	- Offer a repository of NBS reports, data, case studies on climate change impacts, and adaptation measures; - Provide tools for assessment and adaptation planning tools and access to expert advice; - Foster connections and knowledge sharing among stakeholders.	https://climate-adapt.eea.europa.eu/en (accessed on 10 September 2024)
NetworkNature	- Provide a repository of evidence on NBSs; - Strengthen partnerships and foster local, regional, and international cooperation.	https://networknature.eu/ (accessed on 10 September 2024)
Oppla	- Offer a repository of NBS project sites, case studies, and online resources; - Facilitate knowledge sharing and collaboration among stakeholders.	https://www.oppla.eu/ (accessed on 10 September 2024)
ThinkNature	- Identify regulatory, economic, technical obstacles to NBS implementation; - Facilitate dialogue and interaction on NBSs through discussion forums and debates.	https://cordis.europa.eu/project/id/730338 (accessed on 10 September 2024)
Urban Nature Atlas	- Offer comprehensive database of urban NBS evidence in cities worldwide; - Offer opportunities for users to submit and update their own NBS case studies.	https://una.city/ (accessed on 10 September 2024)

The rich experience gained from NBS projects in various European cities offers Asian urban planners and researchers an insight opportunity to learn from best practices and address the unique challenges of their local contexts [42]. To ensure the effectiveness of NBS development and implementation in Viet Nam, careful monitoring of local conditions, such as hydrological patterns, soil conditions, vegetation, land use changes, and socio-economic factors, is essential for adapting and refining monitoring standards and assessment criteria.

Building an NBS infrastructure requires a large amount of finance, which the central government is reluctant to provide. It is important to attract funding from public–private sector groups and international organizations. Between 2011 and 2020, Viet Nam successfully mobilized funding from various international organizations to support sustainable development and climate change response. However, as the country has transitioned to a middle-income status, international funding sources have begun to decrease. This shift necessitates Viet Nam's adaptation of its resource mobilization strategies to address climate change challenges [80].

To encourage the private sector to participate in SC financing and promotion, the Chinese government has implemented the public–private partnership (PPP) model which is involving private companies in the construction and operation of projects under government control, creating a collaborative investment approach between government and private sectors.

The European Union (EU) dominates funding for NBS projects across Europe. In addition to EU funding, national and regional governments in Europe also allocate funding for NBS initiatives, which include national budgets, regional development funds, and public–private partnerships [86]. Other funding sources for NBS projects come from private sectors or international development organizations. A report by the European Investment Bank's Innovation and Digital Finance Advisory Division [86], funded by the EU, interviewed 22 NBS projects' managers. The vast majority (90%) of financing sources for these projects came from public sources. Of this, 73% was provided by the Horizon 2020 program or EU LIFE program (for the environmental and climate policy of the EU), while municipal grants represented the second largest funding source (23%).

The rapid growth and development of cities underscore the importance of incorporating NBSs into the planning and designing phase, rather than retrofitting, which is often the case in already urbanized regions such as Europe. Retrofitting existing urban areas can be costly and challenging due to infrastructure constraints and complex planning processes. While NBSs can be implemented in retrofitting projects, they may offer only short-term solutions if not supported by long-term planning and strong commitments. Thus, it is imperative to formulate a long-term vision and strategies for the integration of NBSs.

6. Conclusions

This study aimed to clarify the development of urban water management in Europe and Asia (with a particular focus on China and Southeast Asia) and the drivers for implementing nature-based solutions (NBSs) in Viet Nam. It also sought to explain the barriers to NBS adoption, illustrate feasible solutions for NBS uptake, and explore future perspectives of NBS development in the context of Viet Nam.

The review highlights a significant gap in NBS research and implementation in urban water management in Viet Nam and Southeast Asia, especially when compared to the extensive work in China and European countries. This disparity underscores the urgent need for focused research and the development of tailored NBS strategies in these regions, particularly in light of the unique challenges posed by their urbanization patterns and climatic conditions.

The limited number of studies on NBSs in Viet Nam and Southeast Asia indicates that these regions are still in the early stages of exploring and implementing NBSs. This contrasts sharply with the more advanced stages of NBS application in Europe and China, where numerous projects have been implemented and extensively studied. This gap in knowledge and practice suggests an opportunity for future research and pilot projects in these regions, which could serve as models for other developing countries facing similar challenges.

Several barriers to the adoption of NBSs in Viet Nam and Southeast Asia have been identified, including high urban population density, the region's unique climatic conditions, technical challenges, and financial constraints. Addressing these barriers requires a multifaceted approach, including capacity building, the development of region-specific technical guidelines, and securing funding from both public and private sources.

The experiences of China, particularly with its Sponge City Program, offer valuable insights that could be adapted for Viet Nam and other Southeast Asian countries. Establishing partnerships with countries that have successfully implemented NBSs could facilitate the transfer of knowledge and technology, helping to overcome some of the technical and financial barriers identified.

The rapid urbanization and development in Viet Nam highlight the importance of incorporating NBSs into the early stages of urban planning and design. Retrofitting existing urban areas with NBSs can be costly and complex and may not always be feasible due to existing infrastructure constraints. Therefore, a proactive approach that integrates NBSs into new urban developments from the outset is crucial for maximizing their benefits. The primary drivers of most decisions in development planning and the implementation of NBSs for climate resilience and adaptation in Viet Nam are governance and economic factors.

Looking forward, the development of NBSs in Viet Nam will require a long-term vision and strategic planning. This includes fostering collaborations between governmental agencies, academic institutions, and international organizations to develop and implement comprehensive NBS strategies. Additionally, there is a need for greater public awareness and community involvement in NBS projects to ensure their sustainability and effectiveness.

To advance the adoption and implementation of NBSs in Viet Nam and other Southeast Asian countries, it is imperative to increase investment in research to develop NBS technologies and strategies specifically tailored to the climatic and urban conditions of Southeast Asia. This research should focus on identifying the most effective NBS approaches for managing urban water challenges in the region. Furthermore, it is essential to develop training programs and workshops for local engineers, urban planners, and policymakers to enhance their understanding of NBSs and build the technical capacity needed to implement these solutions effectively.

Integrating NBSs into national and local policies related to urban planning, climate change adaptation, and water management is crucial. Policymakers should be encouraged to adopt NBSs as a key component of their strategies for building climate resilience. Additionally, exploring innovative funding mechanisms, such as public–private partnerships, international grants, and climate finance, will be necessary to support the implementation of NBS projects. Governments should also consider providing incentives for private sector investments in NBSs.

Finally, increasing efforts to raise public awareness about the benefits of NBSs through educational campaigns and community-based projects is vital. Engaging local communities in the planning and implementation of NBSs can help ensure their long-term success and sustainability.

The findings of this study can inform the implementation of NBSs in other developing countries with similar tropical climates and urbanization patterns. In conclusion, Table 5 outlines the key challenges for promoting NBS implementation in Viet Nam, along with recommendations and opportunities for future research.

Table 5. Constraints and recommendations for the promotion of NBSs in Viet Nam.

No.	Constraints	Recommendations	Opportunities for Future Research
1	Lack of legal policies and technical guidelines	Policies, guidelines, and design criteria must be established; Implementation of a comprehensive and integrated citywide strategy or master plan for NBS implementation; Close coordination among central, local governments and stakeholders.	Mainstream NBSs in Viet Nam legislation, which provides a key opportunity to influence their implementation; Develop tools for managing legal document systems, supporting effective implementation; Develop in-depth analysis of design, monitoring, and performance evaluation systems and develop national, local guidelines; Model with cost–benefit analysis can bring insights for decisionmakers into the investment of NBSs;

Table 5. *Cont.*

No.	Constraints	Recommendations	Opportunities for Future Research
2	Climate context and urban patterns	Integration of local sites and climate characteristics to select the best possible solution for NBS implementation; Combined "green + grey" approach; Creation and development of databases and measurement networks that support the planning and modeling of NBSs.	Modeling studies for extreme rainfall events (5-, 10-, 25-, 50-, 100-year design storms) are essential. Design storm modeling for NBS designs have to be based on local rainfall conditions and urban patterns, preferably from case studies in regions with similar climatic conditions and urban characteristics.
3	Research capacity and technology	Establishing partnerships with countries that have successfully implemented NBSs could facilitate the transfer of knowledge and technology and overcome technical and financial barriers; Develop training programs and workshops for local engineers, urban planners, and policymakers to enhance their understanding of NBSs and build the technical capacity needed to implement NBS projects.	Hydrological modeling, employing a variety of models, can provide significant insights into the urban water systems and their environmental benefits, through: (i) examining the impacts of NBSs on different aspects of the hydrological cycle; (ii) identifying appropriate areas for NBS implementation; (iii) determining effects of single and combined NBS measures in mitigating urban flooding, improving water quality, enhancing ecological services, etc.
4	Research funding and budget constraints	Establishing partnerships with countries that have successfully implemented NBSs could facilitate the transfer of knowledge and technology and overcome technical and financial barriers; Develop funding mechanisms in implementing NBS projects such as public–private partnerships, international grants, and climate finance; Improve investment environments by strengthening regulations and providing incentives to attract greater funding and green finance.	
5	Public awareness and involvement	Raise public awareness though educational campaigns and community-based projects to engage local communities in the planning and implementation of NBSs.	

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16208812/s1, Table S1. List of papers, their distribution per region or country, and their content types; Table S2. PRISMA 2020 flow diagram for the systematic review.

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