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STRATEGIES TO OVERCOME IMPLEMENTATION BARRIERS OF URBAN NATURE-BASED SOLUTIONS FOR CLIMATE CHANGE ADAPTATION: A GLOBAL OVERVIEW FROM A CROSS COMPARATIVE STUDY

by
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ABSTRACT

OF THE THESIS OF

Johny Samir Tannous for Master of Science in Environmental Sciences
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Title: Strategies to Overcome Implementation Barriers of Urban Nature-Based Solutions for Climate Change Adaptation: A Global Overview from a Cross Comparative Study

Urban areas worldwide are increasingly facing intensifying climate change impacts like flooding, heatwaves, and droughts. In response, employing nature-based solutions (NBS) in cities has emerged as a promising adaptation strategy for counteracting these intensifying climate impacts. Specifically, NBS leverages sustainable, green infrastructure approaches inspired by natural processes to enhance climate resilience and adaptation of urban settlements. However, multiple systemic barriers have hindered the broader adoption and implementation of NBS interventions. This thesis sheds light on strategies for dismantling such barriers through an in-depth case study analysis.

The study analytically examines 103 successfully implemented NBS initiatives across diverse global cities to elucidate real-world strategies for overcoming implementation barriers. The cases unveiled interconnected barriers spanning four key dimensions – policy, knowledge, collaboration, and financial. Outdated regulations and institutional resistance frequently obstruct NBS uptake, coupled with gaps in technical capacity and multi-stakeholder coordination.

To overcome the uncovered systemic barriers, the case studies revealed that it is important to employ implementation strategies including participatory policymaking; strengthening collaborative abilities by facilitating diverse partnerships; fostering robust knowledge networks for technical assistance; generating evidence of effectiveness via pilot demonstrations; and enhanced financing access through creative models. Specific enablers like communication campaigns, knowledge sharing platforms, regulatory reforms and technical training also prove impactful for mainstreaming NBS.

As urban settlements worldwide face mounting threats from climate change, adopting holistic implementation perspectives becomes imperative. This research also provides guidance for decision-makers on implementing NBS to systematically dismantle existing sustainability adoption barriers. The developed framework lays implementable roadmaps for mainstreaming nature-based approaches to enhance urban adaptation globally. Enabling broad NBS integration through combinations of social, institutional, knowledge and economic interventions constitutes a pathway for building climate-resilient, sustainable cities globally. With intensifying climate impacts, these findings can facilitate urgent green transformations worldwide.

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ABBREVIATIONS

NBS	Nature Based Solutions
IPCC	Intergovernmental Panel on Climate Change
EbA	Ecosystem-based Adaptation
CO2	Carbon Dioxide
CCA	Climate Change Adaptation
BGI	Blue-Green Infrastructure
LID	Low Impact Development
EEA	European Economic Area
IUCN	International Union for Conservation of Nature
GI	Green Infrastructure
UNEP	United Nations Environment Program
UNEA	United Nations Environment Assembly

CHAPTER 1

INTRODUCTION

As a result of Climate change, global warming is intensifying dramatically (UN, 2022). In fact, the earth is now warming at a faster rate than any instance in the history of climate records (UN, 2022). This poses great threats to human beings, ecosystems, biodiversity and all forms of life on earth. These impacts include extreme weather events, sea level rise and others (UN, 2022). Causes of climate change are attributed to anthropogenic sources of material extraction, extensive CO2 emissions due to industrialization and transport and the reluctant societies and economies to switch to sustainable sources of energy and development. Many of the above causes are a result of increased population and wealth, and therefore increased demand for resources; and many of these resources are usually used by inhabitants of cities. While it can be said that cities are contributing to climate change, the focus of this thesis is on the impacts of climate change on cities.

Climate change significantly impacts cities globally (UN, 2022). Knowing that more than 50% of the global population lives in cities. In fact, urban areas are experiencing direct effects of climate change. Cities are facing challenges such as increasing extreme weather events (e.g. droughts and flooding periods) to localized effects such as urban heat island effect (Hanson et al., 2020). At the same time, global urbanization trends are responsible for the conversion of large-scale natural land areas to urban areas, which is part of the anthropogenic development that accentuates the impacts of climate change (Cannop et al., 2016). For the sake of contextualizing the situation, the UN report (2022) and the World Bank (2022) explained that more than two-thirds of the world population is projected to live in cities by 2050. Furthermore, population growth and urbanization pose great changes on land use patterns and accentuates land usage and development patterns which inflict further pressure on human well-being and ecosystem functionality (Kabisch et al., 2017). Therefore, sustainable urban development and climate change adaptation are referenced as major global societal challenges (Kabisch et al., 2017; Cohen-Shcham et al., 2019; European Commission, 2018a) to be addressed in the very near future. With cities facing complex interrelated challenges of climate change, integrated strategies are needed to draw on ecological and social systems for effective, equitable climate adaptation. Cities are comprised of multiple interconnected systems across sectors such as energy, water, transportation, housing, and health that all face disruption from shifting climate patterns (Araos et al., 2016). While advances have been made in areas like emergency preparedness, infrastructure resilience, and climate-conscious planning, cities require holistic strategies that address the human facets of vulnerability along with environmental risks (Amundsen et al., 2018). Adding on this intersectional nature of climate adaptation, Denton et al. (2014) state that *"adaptation planning and implementation can be enhanced through complementary actions across levels ... taking account of impacts elsewhere to avoid maladaptation"* (p. 19). As such, a key emerging priority is to incorporate natural, financial and social mechanisms simultaneously into integrated climate planning, leveraging synergies between interlinked human and environmental urban systems.

The discourse in the field of climate change and urban sustainability and development is more frequently including a new emerging concept, Nature-Based Solutions (NBS). NBS is deemed as a promising approach to address issues related to urban climate change adaptation and urban sustainability (Kabisch et al., 2017). In fact, NBS is one effective way to address climate change adaptation (CCA) in urban areas (Bauduceau et al., 2015; Kabisch et al., 2017; Hanson et al., 2020) by incorporating green infrastructure and sustainable ecosystem management approaches that harness regulatory services, providing cooling, flood mitigation, clean air, and enhanced resilience in the face of climate impacts. This concept is defined by the European Commission (2018a) "as actions inspired by nature taken to preserve, sustainably manage, and restore natural or modified ecosystems with the goal of addressing societal issues and promoting biodiversity and human welfare" (p.1). Hence, NBS generate short-term benefits and contribute in building long-term resilience for future and unforeseen impacts of climate change (Bauduceau et al., 2015). In addition, NBS is recognized for having an important potential to reduce vulnerability to weather-related events thus enhancing city resilience and adaptation to climate change (EEA, 2021). Furthermore, NBS can provide numerous other benefits ranging from enhanced social cohesion to increased real estate market, and various ecological benefits (Raymond et al., 2017).

Despite being acknowledged for its potential, the implementation of NBS in a general context as well as specifically for climate change adaptation in urban areas remain very limited (Kabish et al., 2017; Castellari, et al., 2021; Hawxwell, et al., 2019). In fact, since 2016, NBS gained increased attention in numerous disciplinary research fields such as biodiversity, urban planning, political science and economics. However, very few academics and researchers have looked at and investigated the reasons for the lack of sufficient number of implemented NBS projects. In fact, a limited number of recent studies identify barriers to NBS implementation. The barriers identified in existing research exhibit geographic specificity, with studies focused on particular locations or regions (e.g. Dorst et al., 2022; Raška et al., 2022; Sarabi et al., 2019; Cohen-Shacham et al., 2019), rather than providing a comprehensive global analysis. These barriers are deemed as the challenges, constraints, hurdles or obstacles that impede urban NBS implementation (Sarabi et al., 2019). Example of such barriers include silo-based disciplinary work structures, lack of awareness, lack of public approval and support, lack of funding, and lack of political support (e.g. van der Jagt et al., 2019; Dorst et al., 2021; Raška et al., 2022). Therefore, it is crucial to overcome these barriers to enhance urban NBS implementation. This can be achieved by employing strategies or enablers for implementation. However, limited research was focused on strategies or elements that facilitate NBS implementation processes (Dorst et al., 2022; Castellari et al., 2021). On the other hand, factors such as knowledge sharing, collaborative governance structures and legislations were identified as important enablers for NBS implementation (Kabisch et al., 2017; Nesshöver et al., 2017; Van der Jagt et al, 2020).

While existing research attempted to identify barriers and strategies to implementing NBS, comprehensive examination of concrete strategies to systematically overcome barriers to urban NBS implementation remains lacking (Dorst et al., 2022; Mendes et al., 2020; van der Jagt et al., 2020). This gap is especially pronounced within the sphere of climate change adaptation contexts (Kabisch et al., 2022). Without systematic focus on realistically overcoming NBS implementation barriers, cities face heightened climate vulnerability (Mees and Driessen, 2019). Additionally, studies and research that tackled NBS implementation are limited in geographical context, which emphasizes the need for additional comprehensive global research regarding this topic. Moreover, most studies simply provide overviews or lists of barriers rather than indicating how frequently actors encounter them. However, frequency is very important to prioritize potential barriers especially because assessing the regularity at which barriers arise enables evidence-based prioritization of which barriers may warrant priority intervention, facilitating strategic targeting of common challenges that have an outsized influence in hindering implementation if unaddressed. (UN, 2022). Hence, a clear literature gap persists regarding providing actionable pathways/strategies for overcoming prevalent barriers to embedding nature-based approaches in urban infrastructure planning and development processes worldwide. Consequently, this research will aim to answer the following question:

What are the practical strategies to overcome barriers to implement urban Nature Based Solutions for Climate Change adaptation?

In this research, implementation is defined as the process of executing and realizing a NBS project, thus referring to implementation in both the beginning and endpoint stages.

The main objectives of the research are:

- To identify barriers that hinder the implementation of NBS projects for climate adaptation in an urban context.
- To contextualize the frequency of the encountered barriers.
- To explore strategies that key actors use to overcome NBS implementation barriers for climate adaptation in urban contexts.
- To develop new emergent NBS implementation strategies based on comparative case study analysis.

In order to answer the research question and fulfill the objectives of the research, several global NBS case studies for CCA were selected from five major databases as explained in the methodology section below. In addition, this research is purely qualitative in nature following multiple case study analysis technique (Yin., 2015). This means that the researcher mainly analyzed multiple case study reports to identify and extract relevant data that serve to fulfill the objectives of the research. The extracted data was coded and processed using Nvivo 14 pro software and analyzed following the pattern matching analysis technique and cross-case synthesis technique developed by Yin (1994 and 2014).

CHAPTER 2

LITERATURE REVIEW

2.1 Impacts of Climate Change on Urban Areas

The impacts of climate change on urban areas are intensifying worldwide (UN, 2022). They mainly include extreme weather events, sea level rise, intensifying heat waves, frequent and intense drought periods, severe alteration to ecosystems resulting in drastic geographic changes of several plant and animal species, longer and frequent flooding periods, water scarcity, increased aridity, air pollution and heat stress (IPCC, 2022). In addition, urban regions are particularly sensitive to climate change due to certain local unique factors that shape their microclimatic conditions qualifying cities as hotspots for risks and disasters (IPCC, 2022). The interaction between these specific microclimatic conditions and climate change, exacerbate climate risk (European Commission, 2018a).

Impacts of climate change on cities do not occur in siloes, rather, they interact with other natural, financial and social factors such as rapid urbanization, increasing water demand, changing demography (particularly the elderly, who are more vulnerable to heat waves) and socioeconomic factors that influence risk and vulnerability of people, infrastructure and ecosystems (EEA, 2021; Mendes et al. 2020). The interaction of such numerous elements, including climate change, severely influence urban regions. A good example of such interaction would be the urban heat island (UHI) effect, where an increase in ambient temperature is further induced along urban areas due to reduced vegetation and evapotranspiration, an increase in heat production due to anthropogenic activities and higher prevalence of dark surfaces that have low heat reflecting properties (Mendes et al., 2020). Another example is climate induced flooding where not only it induces infrastructural and ecosystem health damage and directly impacts human lives, but also poses human health hazards by introducing toxins into rivers and lakes through overloaded urban sewage systems (Metcalfe, et al., 2017). Hence, these interactions have significant economic and social consequences, resulting in financial loss, inconvenience to individuals, and in many cases, loss of life (Mendes et al., 2020).

An important factor that further amplifies the impacts of climate change and needs to be accounted for is population growth (UN, 2019). In fact, it was noted in 2021 that cities house more than half of the world's population and it is also expected that the world's urban population will be more than 6 billion by 2045 (The World Bank, 2021). Given that urbanization is continuously increasing, this contributes to intensifying but also means that a larger population of the world would also be exposed to the direct impacts of climate change (Metcalfe et al., 2017). As a result, here comes the need for climate change adaptation (CCA) in cities, where it serves as an important tool that alleviates the negative impacts of CC on the population and the environment.

Two primary paths exist for responding to intensifying climate change impacts - mitigation to reduce greenhouse gas emissions and slow further changes, and adaptation to adjust communities and systems to actual or expected effects (IPCC, 2022). While mitigating emissions is crucial to limit long-term climate alterations, it alone cannot prevent all impacts from the present atmospheric greenhouse gas concentrations and associated effects. This necessitates complementary adaptive actions that strengthen systemic and community resilience, enhancing capacities to endure and recover from intensifying climate disruptions. This is especially true in dense urban areas facing both localized and global climate effects (Mendes et al., 2020). With complex-built infrastructures coupled with human populations, cities require context-specific climate adaptation measures to reduce vulnerability of residents and interconnect social, ecological, economic, and technical facets enhancing livability (Araos et al., 2016). As climate change catalyzes new configurations of urban risks, sustained adaptation policies and initiatives enable cities to protect wellbeing while optimizing co-benefits across sectors. Therefore, this thesis focuses specifically on climate change adaptation for cities which serves as an indispensable tool for alleviating negative impacts on both human and environmental systems (Mendes et al., 2020).

2.2 Climate Change Adaptation

IPCC (2022b) defines climate change adaptation as the process of adjusting to a given or anticipated climate and its impacts in order to reduce harm or take advantage of beneficial opportunities. The process of adapting to the real climate and its impacts occurs on its own in natural systems, however, it is important to understand that human intervention make it easier to adapt to the anticipated climate and its effects (IPCC, 2022b). Thus, adaptation can be a process, action, or result that aids the system in better coping with, managing, or adapting to the changing circumstances, pressures, hazards, dangers, or opportunities connected with climate change (IPCC, 2022b).

In human systems, adaptation planning often comprises an iterative process of risk management, and it is often seen as having five general stages: "(a) awareness, (b) assessment, (c) planning, (d) implementation and (e) monitoring and evaluation" (IPCC, 2022b p.134). Actors in the public and private sectors have created a wide range of specialized adaptation strategies that, in varied degrees, address these five main stages.

There are different types of adaptation pathways (IPCC, 2022b) and include autonomous adaptation, community-based adaptation, ecosystem-based adaptation (EbA), evolutionary adaptation, incremental adaptation and transformational adaptation. Table 1 summarizes these different types.

Table 1. Strategies for climate Change adaptation

Adaptation option	Description
Autonomous adaptation	Adaptation in reaction to actual climate and its impacts, rather than planning specifically or intentionally with climate change in mind. Also known as spontaneous adaptation. (IPCC, 2022b).
Community-based adaptation	Local, community-driven adaptation. The emphasis of community-based adaptation is on empowering and increasing communities' ability for adaption. It's a strategy that views the context, culture, expertise, agency, and preferences of communities as assets. (IPCC, 2022b).
Ecosystem-based adaptation (EbA)	Ecosystem management practices make people and ecosystems more resilient to climate change and less vulnerable to it. Common management practices include: **Nature-based solution (NBS)** (IPCC, 2022b).
Evolutionary adaptation	The process through which heritable features are chosen to help a species or population adapt to a changing environment. The distinction between acclimatization and evolutionary adaptation is often made by biologists, with the latter taking place over an organism's lifetime. (IPCC, 2022b).
Incremental adaptation	Adaptation that at a specific scale, preserves the integrity and essential characteristics of a system or process. In some circumstances, incremental adaptation may build up to transformational adaptation. Incremental adaptations to climate change are defined as continuations activities and behaviors that reduce the losses or increase gains from natural changes in extreme weather/climate occurrences. (IPCC, 2022b).
Transformational adaptation	Adaptation that modifies a social-ecological system's core characteristics ahead of climate change and its effects (IPCC, 2022b).

Hence, cities have numerous options to advance climate adaptation, from enhancing disaster preparedness to upgrading infrastructure (Araos et al., 2016). Many pathways incorporate ecological principles using nature-based solutions (NBS). For example, urban reforestation programs cool heat islands while absorbing stormwater, and wetland restoration buffers flooding and filters runoff (Kabisch et al., 2016). Such ecosystem-based adaptation leverages regulatory services that boost urban resilience across sectors. Other approaches involve community-centered adaptation where cities co-produce policies with vulnerable groups to ensure inclusive, equitable outcomes (IPCC, 2022). Incremental improvements also accumulate resilience benefits over time by continually incorporating climate considerations into planning.

Ultimately, transformational adaptation involves reconfiguring urban systems for livability under emerging climate regimes (Pelling et al., 2015). However, change often occurs through hybrid pathways mixing incremental, ecosystem-centered, community-engaged and systemic approaches matched to local contexts (Wise et al. 2014). As cities advance adaptation efforts, explicit focus on equitable ecosystem-based initiatives can provide multiple risk reduction, health, and sustainability co-benefits vital for urban climate justice and resilience. Therefore, this thesis focuses specifically on barriers and strategies for effective ecosystem-based adaptation deployment in cities to inform urgent climate action globally.

2.3 Ecosystem-based adaptation

Ecosystem-based adaptation (EbA) is increasingly recognized and adopted by cities as an indispensable strategy to mitigate the environmental impacts of urban development, improve climate resilience, and promote green urban transition and sustainability in the face of climate change (Kabish et al., 2022). Climate change exacerbates urban challenges such as more frequent flooding, intensified heat island effects, worsening droughts, and heightened pollution levels. EbA offers adaptive solutions to strengthen climate resilience in cities against these impacts (Kabish et al., 2022). EbA fundamentally relies on the conservation, restoration, or even creation of ecosystems integrated with development practices to maintain or harness ecosystem functions and services for building resilience and sustainability in a changing climate (IPCC, 2022). EbA uses nature-based solutions to handle intensifying climate impacts. Major examples of EbA include nature-based solutions (NBS), blue-green infrastructure (BGI), and low impact development (LID) in the context of urban water management. NBS involve the protection and management of natural and semi-natural ecosystems to provide benefits like flood control, heat mitigation, and pollution reduction in the face of climate change related impacts (Nesshover et al., 2017). BGI integrates traditional grey infrastructure with green elements like wetlands, bioswales, and green roofs to enhance stormwater management, water quality, and community livability as precipitation patterns change (Ghofrani et al., 2017). LID encompasses design approaches that use natural hydrological features to manage increased stormwater runoff and worsening floods due to climate change (Eckart et al., 2017).

EbA approaches like these are now being practiced not just in developed countries, but also increasingly in developing countries around the world (Afriyanie et al., 2020; Hamel & Tan, 2022).

Climate change is also causing more intense storms, flooding, erosion, and sea level rise which is threatening coastal communities (Hamel & Tan, 2022). An EbA project could restore degraded coastal mangrove forests to specifically address these climate impacts. Mangroves provide many services that enhance resilience, including attenuating storm surges worsened by climate change, controlling erosion exacerbated by sea level rise, and capturing carbon to help mitigate further climate impacts (Hamel & Tan, 2022). Communities near these restored mangrove areas would directly benefit from reduced risk to intensifying storms and rising seas due to climate change. The mangroves themselves would also be more likely to survive future climate impacts like inundation and erosion (Hamel & Tan, 2022).

Other examples of EbA activities include sustainable forest management to regulate water flows against climate-driven droughts and floods, agroforestry practices that boost agricultural yields to improve food security threatened by climate change, and conservation of biodiversity-rich grasslands vulnerable to changing precipitation and temperature patterns. A key advantage of EbA is that it often provides multiple co-benefits, like habitat protection and increased carbon sequestration, to both adapt to current climate impacts and build resilience to future effects (Hamel & Tan, 2022).

Compared to hard infrastructure approaches like building seawalls or levees, EbA is frequently more cost-effective and sustainable (Afriyanie et al., 2020). EbA addresses root causes of climate vulnerability rather than just impacts. It tends to enhance the capacity of ecosystems to continue providing services as the climate changes. EbA also promotes flexible adaptation plans that can adjust to uncertainties (Ghofrani et al., 2017).

Hence, ecosystem-based adaptation refers to the use of nature and natural systems to help people adapt to climate change. By sustaining ecosystems, EbA boosts community resilience and provides a host of co-benefits. As climate change accelerates, EbA offers an essential approach for adaptation, coupled with other measures.

2.4 Nature-based Solutions

As highlighted in the previous section, climate change adaptation is deemed as an important approach to alleviate the negative impacts of CC on the population and the environment (IPCC, 2022b). In order to achieve CCA in cities, much of the current discourse in the field of climate change and urban sustainability revolves around NBS (Raška et al., 2022; Kabisch et al., 2022). In fact, NBS are framed as one of the most promising tools and actions to achieve sustainability and climate change adaptability in urban areas (Kabisch et al., 2022)

2.4.1 Definitions of Nature-based Solutions

There is no single definition of NBS given that the term is relatively new. Ongoing debates exist over what to include in the concept (Hanson et al, 2020). However, the most referenced definition is the one developed by the IUCN, which coined the term NBS. The definition emphasizes that NBS are "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g., climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (IUCN, 2015, p.1).

The European Commission (2018b) further elaborated and articulated the IUCN's NBS definition in the context of cities and stressed that these are "Solutions 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 more and more diverse nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions (p.1)".

In addition, the definition was constantly developed overtime and the United Nations Environment Program (UNEP) during the United Nation Environment Assembly

(UNEA) on March 02, 2022 emphasized the need for a multilaterally agreed upon definition of the concept and contributed to the definition by stressing on a variety of criteria and factors for the application of NBS, such as social and environmental protection (UNEP, 2022). Thus the most current definition, and the one adopted for the purpose of this research, entails the following: "NBS are actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits" (UNEP, 2022, p.3)

It is also important to note that NBS are frequently viewed as a flagship term or a key concept that can encourage governments, businesses, the public, and organizations to develop novel ways of including natural capital in planning strategies and policies while maintaining ecosystem services and human well-being (European Commission, 2018b; Cohen-Shacham et al., 2019). The concept is heavily promoted in Europe and is considered as an umbrella term for various green concepts such as Green Infrastructure (GI) and is strongly dependent on concepts that stem from the green concept approach (Hanson et al., 2020) and ecological systems thinking.

In order to distinguish NBS from other green concepts, the IUCN in 2020, created a worldwide standard for NBS that also guarantees an effective management and implementation process. The standard includes eight criteria for sustainable development that take economic, environmental, and societal considerations into account (IUCN, 2020). The following is a summary of the eight criteria: (1) address social issues that have been prioritized (2) promote NBS designs that consider landscape complexity and unpredictability (3) produce net benefits in relation to ecosystem services; (4) are economically feasible (5) support a transparent governance process and address the concerns of key stakeholders (6) Maintain the trade-off between the core goal and any other advantages; (7) Manage the NBS in an adaptive manner; and (8) Be planned and maintained with the long term perspectives in mind (IUCN, 2020).

2.4.2 Nature Based Solutions and Climate Change Adaptation

It is clear that the concept of Nature-Based Solutions is gaining increased popularity particularly when it comes to taking advantage of what nature offers in order to address urban challenges sustainably (Cortinovis et al., 2022). In addition, NBS's wide range of co-benefits make them cost-effective from a medium- to long-term perspective, which is why calls to use NBS instead of or in conjunction with more conventional grey infrastructure measures are becoming more prevalent (Cortinovis et al., 2022).

Among the multiple benefits of NBS is their ability to enhance city adaptation to climate change, which is one of the main challenges that urban areas will particularly face in the upcoming years (Cortinovis et al., 2022; Kabisch et al., 2022). Climate change is already affecting cities through impacts like heat waves, floods, droughts, and storms, which are projected to worsen. NBS can help cities build resilience to these impacts in a sustainable way.

In fact, Nature based solutions for Climate Change Adaptation include a range of solutions that aim to address climate-related problems, especially those that affect urban areas. Use of green and blue infrastructure to combat rising temperatures and heat waves is one example. This might entail creating parks, planting trees and other types of vegetation, or installing green walls and roofs that have a cooling impact (Kiddle et al., 2021). Hydrological effects of climate change can also be addressed by NBS. These can include, for example, bioswales, green roofs, and rain gardens, which are channels created to concentrate and transmit storm water runoff. These serve to prevent floods and lessen the adverse consequences of storm events (Kiddle et al., 2021).

Along with addressing intensifying climate change impacts like heat waves and floods, nature-based solutions (NBS) provide additional sustainability and well-being co-benefits for cities and their residents. By integrating green space and ecosystem elements into the urban landscape, NBS enhance living quality through improved aesthetic value and recreational opportunities (Neufeldt et al., 2021). Contact with natural environments has also been linked to better physical health outcomes like reduced cardiovascular disease, decreased premature mortality, and faster healing times (Twohig-Bennett & Jones, 2018). From a mental health perspective, biodiverse urban nature access presents associations with restored cognitive function, stress relief, and emotional wellbeing (Hunter et al., 2019). NBS strategies also facilitate community building and stronger cultural identities by providing public park venues for social gatherings and integrating meaningful native ecosystem elements (Chan et al., 2022). Another crucial co-benefit of nature-based solutions is reducing climate change exposure and vulnerability for disadvantaged communities. Issues like urban heat islands, flooding risk zones, and pollution hotspots, disproportionately impact low-income neighborhoods and marginalized groups (Hammer et al., 2022). Green space projects that cool vulnerable area microclimates, absorb stormwater, or filter contaminants therefore help decrease threats to overburdened communities. Specific NBS that restrict exposure pathways and buffer impacts include bioswales redirecting floodwaters, lakes serving as heat sinks, restored wetlands filtering polluted runoff, and trees providing cooling shade canopies (Meerow & Newell, 2017). Purposeful NBS planning and equity-focused benefit delivery mechanisms can thus build resilience across full urban populations. In essence, NBS allow cities to build resilience to worsening climate change disruptions in cost-effective ways that deliver multiple sustainability benefits across environmental, social, and economic realms (Neufeldt et al., 2021). Their role in urban climate change adaptation and resilience is only expected to grow given worsening climate disruption globally.

2.4.3 Types of Nature Based Solutions

Nature-based solutions provide cities with an effective approach to adapt to intensifying climate disruptions. While offering substantial co-benefits, their fundamental purpose is building resilience through interconnected activities that synergistically address localized impacts (Hammer et al., 2022). Strategic analysis should guide selection of the optimal nature-based solutions, weighing factors like projected climate threats, vulnerable groups, costs versus benefits, and community priorities (Neufeldt et al., 2021). When carefully chosen and executed, these solutions can considerably strengthen urban climate adaptation while securing wellbeing, environmental, social and economic co-gains. The IPCC (2022) categorizes principal nature-based solutions for climate change adaptation into several types as listed in the table below:

Table 2. Various types of NBS as defined by the IPCC

Type of NBS	Description
Ecosystem restoration	Activities that restore degraded or destroyed ecosystems. Examples include reforestation, wetland restoration, coral reef/coastal restoration, and natural regeneration.
Ecosystem management	Sustainable management practices that maintain ecosystem health and functioning. Examples include sustainable

	forestry, agricultural practices like agroforestry, ecosystem fire management, and watershed management.
Ecosystem creation	Establishing new ecosystems in locations where they did not recently exist. Examples include creation of urban green spaces, artificial wetlands, and coastal defenses such as oyster reefs.
Ecosystem protection	Conserving ecosystems and biodiversity through protected areas, habitat conservation/restoration, and removal of invasive species.
Sustainable use	Managing ecosystems for the sustainable production of food, fiber, water, and other materials to benefit people while minimizing environmental harm.
Infrastructure	Nature-based features integrated into built environments like cities, such as green roofs, bioswales, parks, urban forests, and green walls.
Restoration of cultural ecosystems	Restoring indigenous lands, sacred groves, and community forests to revitalize cultural connections to nature and enhance well-being.
Carbon dioxide removal	Enhancing natural carbon sinks like forests and soils to remove carbon dioxide from the atmosphere through activities like reforestation and soil carbon management.

Globally, ecosystem restoration projects like rewilding wetlands, forest rehabilitation, and coral gardening directly rebuild habitat complexity and revive ecological services that are essential for buffering intensifying climate impacts and stressors like hotter droughts and rising seas (Seddon et al., 2021). Ecosystem management approaches ranging from sustainable forestry enrichment planting to climate-proof agroforestry enhance ecological system health specifically for continued climate regulation functions, such as rainfall capture, flood control, and carbon sequestration, as demonstrated in mixed forest stands with buffered microclimates that facilitate species migration in Nepal (Paudel et al., 2019).

Cities combat worsening urban heat islands and flash flooding exacerbated by climate change through engineered nature-based infrastructure like constructed wetlands, ample parks, and intensive green roofs built to absorb greater stormwater overflow, as exemplified in Beijing case study (Rodak et al., 2019). Appropriately sited greenbelt development and wetland restoration enable supplementary climate control services, with projects in Australia strategically repurposing drained swamp zones to mitigate drought and urban heat trends (Radcliffe, 2022).

Ecosystem conservation also maintains climate-protecting coastal defenses, as with Myanmar’s mangrove expansion explicitly safeguarding carbon stocks and alleviating intensified cyclones and encroaching salts from rising seas (Primavera et al., 2019). Importantly, indigenous land management upholding migratory pathways, controlled burning, and climate-resilient biodiversity accelerates ecosystem adaptation, as studied among Aboriginal Australian groups (Leonard et al., 2013).

Therefore, nature-based approaches like ecosystem restoration, protection and sustainable management each contribute distinct climate adaptation functions, yet intersecting these complementary solutions can further amplify systemic resilience (Kabisch et al., 2017; Castellari et al., 2021; Hawxwell et al., 2019). For instance, actively reestablishing degraded habitats reinstates ecological services and natural capital that provide an underlying foundation enhancing long-term conservation and climate change adaptation (Kabisch et al., 2017). Linking these restoration areas to protected zones and sustainable management practices compounds outcomes, whereby restored regions supply plant materials and wildlife that protected reserves safeguard (Castellari et al., 2021). Meanwhile, protected intact ecosystems conserve vital biodiversity strongholds and carbon sinks that are indispensable (Hawxwell et al., 2019).

Additional synergies emerge from integrating green infrastructure into urban environments, bridging fragments within cities to wider natural ecosystems. Urban nature-based features like parks, green roofs and bioswales improve intra-urban habitat connectivity while offering climate regulating services benefiting both people and wildlife by cooling, flood control and pollution mitigation (IPCC, 2022). Revitalizing indigenous lands and communal areas brings back place-based traditional knowledge and governance approaches that enable locally-driven, ecosystem-centered adaptation pathways. And carbon sequestration through nature-based interventions directly abates climate change itself, further increasing ecosystem resilience (Sarabi et al., 2019).

In essence, implementing complementary solutions across various scales amplifies systemic resilience to intensifying climate disruptions. Strategic combinations also multiply benefits like adaptation and sustainability while minimizing trade-offs (Van der Jagt et al., 2020).

2.4.4 Nature Based Solutions at different scales.

These above solutions can be applied at various scales, from local communities up to entire regions.

At the local level, nature-based solutions may involve urban green infrastructure projects like constructing green roofs, urban forests, and wetland parks. These provide multiple services including air cooling, enhanced stormwater management, recreational opportunities, and biodiversity habitat within cities, as seen with urban ecological networks in European cities (Davies et al., 2015). In addition, the Central Java, Indonesia case study (Susanti et al., 2020) showed that rural communities can utilize local nature-based solutions including agroforestry schemes with integrated field hedgerows and ponds supporting climate-resilient crop yields and soil health. Riparian buffer restoration along waterways enhances water regulation, carbon storage, and pollination services benefitting adjacent villages, evident across projects in Spain's Ebro basin (González et al., 2020).

On a broader scale, comprehensive ecosystem restoration initiatives like connecting large-scale forest habitats can rebuild landscape-level climate resilience through improved water cycling, reduced soil erosion, and biodiversity recovery as demonstrated in China's Grain for Green program (Liu et al., 2022). Additionally, green corridors facilitate increased wildlife migrations and genetic health for diverse species (Castilho et al., 2022).

At regional or transboundary scales, cross-border partnerships enable nature-based solution collaboration between provinces and countries. For instance, the Nicaraguan-Costa Rican cooperation on managing the San Juan River basin showed that integrated watershed management initiatives are sustainably reviving the resilience of rivers facing mounting water stress (Herrera et al., 2022). Broader alliances to expand protected area connectivity also safeguard vulnerable species. It is important to note here, that broad collaboration actions unify knowledge, funding sources, governance approaches, and policy frameworks enhancing the implementation of regional nature-based solutions (Castellari, et al., 2021).

Therefore, spanning local to regional initiatives, nature-based solutions offer interconnected options for strengthening climate adaptation and resilience across scales. However, widespread implementation of nature-based approaches faces numerous deeply entrenched barriers, despite their considerable potential benefits (Seddon et al., 2022). Financial, policy, collaboration and knowledge barriers all constrain NBS uptake globally. Yet promising strategies are emerging which can help overcome barriers to delivering climate-resilient development grounded in nature-based options. Discussion follows on prevalent systemic barriers undermining nature-based solution implementation, which constrain feasible pathways for scaling NBS to global climate adaptation.

2.5 Barriers and strategies to urban NBS implementation

Despite being acknowledged for its potential, implementation of NBS in general and more specifically for climate change adaptation in urban areas, remain limited (Cortinovis et al., 2022; Kabisch et al., 2022; Kabish et al., 2017; Castellari, et al., 2021; Hawxwell, et al., 2019). This emphasizes the idea that there are several factors that impede its implementation. In fact, NBS gained an increased attention in numerous disciplinary research fields since 2016, and many academics and researchers are still looking at and investigating the reasons for the lack of NBS implementation (Dorst et al., 2022 ; Sarabi et al., 2019 ; Cohen-Shacham, et al., 2019) However, research to identify barriers to NBS implementation at a global scale remains limited. Rather, studies have focused on identifying barriers in specific contexts and geographies (eg. Dorst et al., 2022 ; Raška et al., 2022 ; Sarabi et al., 2019 ; Cohen-Shacham, et al., 2019). These barriers are deemed as the challenges, constraints, hurdles or obstacles that impede urban NBS implementation (Sarabi et al., 2019). It is also important to note, the existing research reveals a significant gap - only a minimal portion of studies have robustly investigated concrete strategies for implementing nature-based solutions for climate change adaptation purposes. This demonstrates that proper techniques, policies, economic tools, stakeholder engagement methods and monitoring systems explicitly geared towards enabling nature-based approaches to enhance climate resilience remain largely absent (Kabisch et al., 2022).

2.5.1 Barriers to urban NBS implementation

Implementing NBS for enhancing climate change adaptation requires overcoming barriers that undermine adoption and scaling. Several interlinked barriers span across the political, economic, social, and technological spheres hindering successful implementation. As discussed in the subsequent sections, prevalent challenges include issues around lack of government policies, gaps in actionable knowledge and data resulting in uncertainties regarding NBS efficacy, and deficiencies in capacities and financing (Seddon et al., 2022). Alleviating systemic barriers through targeted interventions tailored to leverage local opportunities provides a strong action plan for unblocking scaled NBS deployment globally. Discussion follows on dissecting principle, aggregated barriers constraining NBS implementation, components which must be overcome to ensure successful NBS implementation.

2.5.1.1 Policy

Two levels of policy barriers obstruct nature-based solutions; municipal policies like strict regulations, landscape limitations, policy conflicts, and extensive consultation requirements; and national policies including lack of integration, bias against long-term solutions, perceptions of sustainability tradeoffs, and overlooking nature-based options in climate adaptation planning. The restrictive municipal regulations and conflicting national frameworks are detailed further below.

Municipal policies: Implementing nature-based solutions at the municipal level is hindered by policy obstacles. Strict regulatory frameworks prevail across agencies, with complicated procedures impeding (Li et al., 2019; Dorst et al., 2022). The existing landscape strategies and public space guidelines are found to be very strict obstructing urban nature-based projects under the excuse of conservation (Dorst et al., 2022; Sarabi et al., 2019; Mommers et al., 2021). In addition, no supportive policies exist to resolve contradicting municipal rules, which complicates the situation further. Additionally, in many cases there is a need for the municipality to identify and consult with relevant decentralized government departments relating to nature conservation due to many local policies which poses an additional burden towards NBS implementation. (Raška et al., 2022; Sarabi et al., 2019; Raymond et al., 2017). Together, these bureaucratic obligations systematically restrain promising nature-based solutions through apparent procedural prudence that belies an “inertia” against novel approaches (Raymond et al., 2017. While presumably aiming to responsibly oversee public spaces and conservation efforts, policies and siloed authorities instead seem destined to limit implementation at each step. Forward progress calls for streamlining approval pathways between agencies, positioning nature-based solutions as vital innovations, and reconciling policy collisions under sustainability principles that welcome, rather than block, a nature-based urban future.

National policies: Nature-based solutions face systemic policy “biases” at the national level that preference visible, rapidly deployed interventions over NBS's long-term, intricate impacts. Despite international commitments, national policies seldom integrate nature-based approaches (Van der Jagt et al., 2020; Sarabi et al., 2019; Neufeldt et al., 2020), overlooking regenerative options even in high-priority climate adaptation planning; the complex, living systems at the heart of NBS confound policymakers focused on concrete projects and quickly measurable outcomes (Neufeldt et al., 2020; Sarabi et al., 2019). This bias entrenches through local policy documents that position sustainability initiatives as competing with nature-based solutions in a "zero-sum landscape" (Van der Jagt et al., 2022; Mommers et al., 2021; Sarabi et al., 2019; Dorst et al., 2022). Such beliefs deprioritize nature-based solutions, blocking projects that could demonstrate systemic carbon sequestration, flood mitigation, heat reduction, and community wellbeing improvements in the longer term (Raška et al., 2022; Hawxwell et al., 2019; Dorst et al., 2022) - outcomes that may exceed conventional built approaches. Until policymakers recognize that the living world works in harmony, not competition, with human systems, nature-based solutions remain sidelined despite their vast potential. Constructively, policy frameworks could proactively incubate nature-based demonstration sites, track holistic social and environmental impacts, upskill program architects in systemic thinking and reciprocal externalities, and position regenerative approaches as central, not ancillary, to climate adaptation and community resilience.

2.5.1.2 Knowledge

Development and advancements: An important barrier that hampers the implementation of NBS is the lack of development of the field of NBS. In fact, there is lack of knowledge about nature-inclusive designs in general (Kabisch et al., 2022; Kabisch et al., 2017; Trell et al., 2019). In addition, it was further elaborated that the current technology is not at its peak and the concept is still in its infancy, which pushes away decision makers due to uncertainties in terms of optimal approaches to planning, designing, implementing, maintaining, monitoring of NBS and expected results (Susca; 2022).

Performance evidence: Numerous knowledge gaps, awareness and data challenges exist when it comes to NBS. Knowledge exchange and knowledge in terms of performance capacities of NBS projects are almost non-existent (Kabisch et al., 2022; Li et al., 2019; Sarabi et al., 2019; Trell et al., 2019). Grey technologies that are supported by engineering expertise are dominant, which impedes the use and development of any other type of technology and solutions, particularly fields related to ecology (Dorst et al., 2021). This poses great challenges for NBS implementation, especially that decision makers and stakeholder rely on quantified tangible data and feel safer when applying standardized and conventional approaches and assessment techniques in order to achieve the targeted goals, be it economic or political (Dorst et al., 2021; Van der Jagt et al., 2021; Zuniga-Teran et al., 2019; Davies & Lafortezza, 2019).

In addition, current knowledge, and traditional assessment tools such as certifications, often do not align with the goals and expected benefits of NBS. Van der Jagt et al. (2021) and Davies & Lafortezza (2019) note that there are gaps in knowledge regarding how to best assess and monitor the implementation and impacts of NBS projects. Many existing assessment tools and certifications were developed to evaluate other types of projects, not NBS specifically. In particular, very few of the expected benefits of NBS are included in the traditional assessment tools and certifications (Van der Jagt et al., 2021; Davies & Lafortezza, 2019). The tools often focus only on certain limited factors and outcomes. As a result, they usually fail to provide a comprehensive, fair assessment of NBS performance across the range of economic, social, and environmental benefits that they can provide. For instance, a certification may analyze the impact of an urban green space project on property values or recreational opportunities, but neglect additional benefits related to improvements in public health, biodiversity, climate resilience, and sustainability that an NBS project also produce (Van der Jagt et al., 2021).

Therefore, current knowledge frameworks and conventional assessment tools like certifications tend to be mismatched with the wide-ranging goals and multiple benefits associated with NBS. This further amplifies existing knowledge gaps about how to accurately evaluate NBS outcomes. There is a need to develop more holistic NBS assessment tools and expand knowledge around NBS assessment/monitoring in order to fully understand NBS benefits and performance. This lack of knowledge of NBS performance and evidence were also explained in many of the studies as highlighted in table 2 below.

Skilled labor and organizational capacities: There are many knowledge gaps related to organizational and human capacities that pose barriers to effective NBS implementation. Key knowledge is often missing from within organizations themselves when it comes to NBS (Susca 2022; Dorst et al., 2022; Sarabi et al., 2019). This lack of internal knowledge spans many operational branches, including:

- Limited ecological knowledge about NBS planning - Organizations may lack staff members properly trained in ecology, environmental science, and natural systems who can provide expertise to guide NBS projects and ensure their ecological appropriateness and sustainability (Mommers et al., 2021).
- Limited construction process knowledge about NBS - Organizations often do not have staff expertise regarding specialized NBS construction techniques, materials, equipment needs, etc. to facilitate the physical implementation of NBS plans (Mommers et al., 2021).

In addition, in many cases, implementing NBS projects proposed in urban development plans created by an organization can conflict with that organization's existing goals and standard operational processes (Kabisch et al., 2020; Susca et al., 2022). This leads to a lack of support for NBS adoption from within the organization itself. Therefore, NBS is framed as disruptive or misaligned with the current business model and practical needs of an organization.

Substantial internal organizational barriers exist regarding human capital gaps in key knowledge areas like ecology and NBS construction, as well as clashes between proposed NBS plans and established organizational procedures and priorities. Addressing these issues through further training, revised protocols, and enhanced leadership buy-in will be critical for facilitating more widespread NBS implementation (Susca 2022; Dorst et al., 2022).

2.5.1.3 Financial

Cost-benefit analysis: Several key financial barriers prevent developers and organizations from building strong cost-benefit cases or business models for implementing NBS (Li et al., 2019; Parr et al., 2016; Kabisch et al., 2017). A major issue is ambiguity surrounding the costs, risks, and benefits associated with NBS approaches (Raška et al., 2022; Kabisch et al., 2022; Sarabi et al., 2019). There is uncertainty regarding budgeting for upfront NBS project expenses, quantifying financial risks like maintenance costs or failure rates, and valuing the long-term economic, social, and environmental returns expected from NBS.

This ambiguity makes integrating green components into existing structural development models financially unviable - it introduces too much uncertainty into revenue projections and standard financial frameworks that developers rely on (Neufeldt et al., 2020; Sarabi et al., 2019). Questions also persist around who will be responsible for taking on the maintenance costs and other expenses associated with urban NBS projects after they are completed (Sarabi et al., 2019; Dorst et al., 2022).

Additionally, for many private companies and firms, implementing NBS is often seen as unnecessary for maintaining or improving legal compliance, market positioning, public reputations, or other established financial priorities (Neufeldt et al., 2020; Sarabi et al., 2019). Altogether, these barriers around unclear costs/benefits, maintenance responsibilities, and misalignment with conventional financial targets restrict the adoption of NBS within organizations.

Demand and investment: There appears to be limited awareness and knowledge among real estate investors and developers about the sustainability issues that could impact asset values (returns on investments) and liabilities (exposure to damage costs and risks) (van der Jagt et al., 2020). As a result, there is inadequate demand and few investment cases being made to adopt NBS approaches that could help mitigate sustainability risks like climate change impacts or improve community resilience (van der Jagt et al., 2020).

Additionally, real estate professionals often question whether customers are willing to pay higher prices for nature-inclusive building features or community amenities (van der Jagt et al., 2020). These NBS elements are still viewed as an expensive luxury that many target demographics of home buyers or tenants may not value. This perception further limits market pulls and adoption of NBS (Donnell et al., 2017).

On the supply side, fierce competition for available land in increasingly dense urban areas, especially from conventional real estate development, is also a barrier, as it limits land resources to implement community-scale NBS projects (Donnell et al., 2017). With space limitations, investors tend to prioritize higher-yielding real estate projects over NBS investments that may provide more indirect, long-term returns (Donnell et al., 2017). This also feeds into the problem of cost-benefit analysis and failure when it comes to establishing business cases for NBS projects.

Therefore, knowledge gaps about how NBS can mitigate sustainability risks, uncertainty about market demand, and spatial constraints/tradeoffs that push investors towards conventional built assets over NBS continue to limit private sector engagement and financing for nature-based approaches (Xing et al., 2017; Pedersen Zari et al., 2021). Addressing these barriers through education, appropriate policy incentives, and innovative economic mechanisms will be key to mainstreaming NBS investment.

Maintenance and monitoring: After urban NBS projects are fully implemented, ongoing monitoring and proper maintenance management is crucial but poses several challenges that create financial disincentives. There is ambiguity and unpredictability regarding what additional expenses might arise for upkeep of NBS sites, including maintenance costs like labor, equipment, materials and potential tax implications (Davies & Lafortezza, 2019). Without clarity on longer-term budget requirements, cities and investors can be deterred from taking on NBS projects.

Furthermore, many urban municipalities have very limited capacity and resources to participate extensively in hands-on NBS operation and management post-construction (Davies & Lafortezza, 2019; Cohen-Shacham et al., 2019). Local government budget constraints restrict their ability to cover the recurring staffing, training, monitoring, and maintenance costs associated with properly administering NBS sites such as constructed wetlands, green stormwater infrastructure or urban forests over their full lifetime (Cohen-Shacham et al., 2019).

With unreliable funding streams from fiscally challenged municipalities, the responsibility for ongoing NBS management would likely need to fall heavily on private landholders or other partners (Kabisch et al. 2022). But they may also lack capacity, expertise, and certainty around cost recovery for those long-term stewardship duties. Altogether, these post-implementation funding and management uncertainties pose financial risks that shift investment away from urban NBS projects.

2.5.1.4 Collaboration and engagement

Public acceptance and engagement: A common attitude labeled "NIMBYism" (Not In My Backyard) has been observed among citizens regarding NBS and other sustainability initiatives. This term refers to the tendency for public support and participation in climate goals to be contingent upon actions/projects not interfering with people's daily lives and personal convenience (Dorst et al., 2022). Additionally, individuals often prioritize their own amenities, affordability, and aesthetics over collective environmental benefits (Dorst et al., 2022). This NIMBYsim phenomenon is more pronounced for certain NBS projects compared to others. For example, a resident may approve of a nearby green park but resist installation of permeable pavement roadways, even though the latter provides greater flood control (Kabisch et al. 2022).

Fundamentally, this resistance stems from a limited public understanding of intensifying climate hazards (Kabisch et al. 2022; van der Jagt et al., 2020). Facing knowledge gaps about local risks, people fail to see the larger context and critical necessity of NBS implementation. This lack of climate knowledge thereby obstructs the delivery of appropriate, urgently needed projects. Moreover, these public knowledge limitations further reinforce broader participation, support, and funding challenges facing NBS plans (van der Jagt et al., 2020).

Lack of collaborative governance systems: Effective NBS implementation often requires coordination across multiple stakeholders and governance bodies with interconnected roles and diverse priorities. However, existing collaborative structures between organizations tend to be complex or siloed (Raška et al., 2022; Raymond et al., 2017; Neufeldt et al., 2020). Entities like government agencies, private developers, NGOs, and local communities usually establish goals, planning processes, and funding mechanisms independently without much cross-disciplinary or cross-sector alignment (Raymond et al., 2017).

This limited approach works against NBS delivery models that call for integrated solutions across areas like water management, transportation infrastructure, parks services, etc. For instance, green stormwater control projects may fall through the cracks since they do not fully conform to any single agency’s narrow views. Breaking down engagement and financing siloes between public and private partners across municipal departments represents a core governance challenge for enabling NBS (Sarabi et al., 2019; Raymond et al., 2017; Neufeldt et al., 2020).

Therefore, complex, and fragmented administrative relationships combined with narrow departmental mandates inhibit the collaborative and coordinated resource allocation essential to the multifaceted nature of NBS. Reform aimed at bridging interagency policy gaps through comprehensive co-creation processes could better support systematic advancement of NBS (Sarabi et al., 2019).

Lack of private sector support and engagement: This is due to the fact that NBS revenue becomes tangible after a long period of time, which discourages the private sector from being involved. Rather the private sector will be oriented towards solutions that allow for fast economic growth, which reduces their willingness to engage in NBS projects (Sarabi et al., 2019)

It is important to note that the literature revealed that these barriers hinder the implementation of NBS in urban areas. In addition, the synthesized themes are highly connected. For example, the lack of collaborative governance system is due to economic uncertainties, lack of proper ecological knowledge along with political complexities (Raymond et al., 2017; Neufeldt et al., 2020).

Overall, as discussed in the preceding sections, prevalent barriers span issues around lack of supportive policies, gaps in actionable knowledge resulting in uncertainties regarding NBS efficacy, and deficiencies in capacities and financing. The key barriers extracted from the literature are summarized systematically in Table 2 below, categorized by barrier type and sub-type. This synthesis of prevalent implementation challenges highlighted across academic sources provides a conceptual foundation. It delineates the principal factors that must be overcome to unlock scaled NBS deployment globally through targeted interventions tailored to leverage local opportunities. The consolidated set of barriers in Table 2 will serve as an analytical basis for coding and examining empirical data on barriers facing NBS implementation within subsequent sections.

Table 3. Synthesis of barriers addressed within the academic research and literature.

Barrier	Type of barrier	Sub-type	Source
No integration in high-priority policy plans	Policy	National Policies	Van der Jagt et al., 2020 ; Kabisch et al., 2017 ; Nesshöver et al., 2017
Perceived high cost of NBS projects	Knowledge	Development and advancements	Kabisch et al., 2022; Beceiro et al., 2022; Pauleit et al., 2017; Li et al., 2019
No demand in investment portfolios	Financial	Demand and Investments	Van der Jagt et al., 2020; Dorst, 2021; Davies & Lafortezza, 2019
No concrete evidence on NBS benefits	Knowledge	Performance evidence	Kabisch et al., 2022; Sarabi et al., 2019; Pauleit et al 2017.,
Silo mentalities/lack of collaboration among various departments and intuitions and disciplines	Collaboration and engagement	Lack of collaborative governance systems	Raška et al., 2022; Raymond et al., 2017 ; Neufeldt et al., 2020
No political will and long-term commitment	Policy	Municipal policies	Hawxwell et al., 2019; Sarabi et al., 2019
Fear of unknowns and risk aversion	Knowledge	Performance evidence	Raška et al., 2022 ; Kabisch et al., 2022; Sarabi et al., 2019.
Lack of guidelines and design standards for monitoring and future maintenance of NBS projects	Knowledge and Financial	Performance evidence & Cost-benefit analysis & Maintenance cost and monitoring	Trell et al., 2019; Kabisch et al., 2017
The concept is emergent and underdeveloped	Knowledge	Development and advancements	Mommers et al. 2021, Sarabi et al., 2019
No public support and no organizational support	Behavioral and knowledge	Public acceptance and engagement &	Zuniga-Teran et al., 2019; Kabisch et al., 2022

		lack of private sector support and engagement	
Lack of urgency among stakeholders and policy makers for NBS implementation	Policy	National and Municipal Policies	Trell et al., 2019; Neufeldt et al., 2020
Lack of skilled workers, knowledge and training programs in implementing NBS projects	Knowledge and organizational	Skilled labor and organizational capacities	Susca et al., 2022 ; Davies & Lafortezza, 2019 ; Kabisch et al., 2022; Sarabi et al., 2019
Limited financial resources and lack of financial incentives	Financial	Cost-benefit analysis & demand and investments	Dorst et al., 2022 Neufeldt et al., 2020 ; Sarabi et al., 2019
Lack of organization between short term plans and long term goals	Knowledge and Financial	Performance evidence & maintenance cost and monitoring	Dorst et al., 2022, Kabisch et al., 2017
No legal frameworks and supportive policies	Policy	Municipal policies	Li et al., 2019; Parr et al., 2016
Growth paradigm that prioritize economic growth oriented projects (e.g. companies that create jobs) over urban green spaces.	Policy & Financial	National policies & Cost-benefit analysis	Kabisch et al., 2017; Trell et al., 2019
Space limitations for NBS implementation	Economic & Political	National policies & Demand and investment	Kabisch et al., 2017; Donnell et al., 2017
Limited ecological knowledge	Knowledge	Development and advancements	Susca et al., 2022; Kabisch et al., 2022; Sarabi et al., 2019; Pauleit et al 2017.,
Citizen engagement challenges	Behavioral/Engagement	Public acceptance and engagement	Zuniga-Teran et al., 2019; Kabisch et al., 2022

The key implementation barriers identified earlier have also been aggregated into broader thematic groups based on commonalities as highlighted in figure 1 below. This consolidation into core themes maintains connectivity to the granular outline of barriers originally extracted from the academic literature while enabling a more targeted analytical lens on aggregated factors hindering NBS deployment.

Figure 1: thematic overview of the newly aggregated barriers

In summary, the literature synthesis reveals a complex web of interconnected financial, policy, knowledge and collaboration & engagement barriers that hinder urban nature-based solutions delivery (Seddon et al., 2022; Sarabi et al., 2019). While valuable in delineating the principal barriers categories, published research remains limited in geographical scope (Van der Jagt et al., 2020; Dorst, 2021; Davies & Lafortezza, 2019) and typically only provides conceptual overviews rather than empirically grounded barrier prioritization. Significant research gaps persist regarding the frequency and relative influence of specific challenges facing real-world NBS projects across diverse global contexts (Davies & Lafortezza, 2019). Quantifying occurrence could enable more targeted adaptation efforts tailored to priority barriers within distinct regions. Furthermore, due to interconnectivity, barriers likely compound one another's effects. Therefore, an integrated mitigation approach spanning policy, financial, knowledge, and collaboration interventions will be essential to systematically unblocking scaled NBS implementation worldwide (Seddon et al., 2022). The research undertaken in subsequent sections aims to directly address these gaps through an empirical assessment of barriers encountered by diverse global experts deploying urban NBS. Hence, the results promise more granular insights to refine the understanding of barriers patterns and inform coherent actions plans for barrier removal.

2.5.2 Strategies to overcome barriers to urban NBS implementation.

Unlike barriers, only a small fraction of the studies investigated strategies that overcome barriers to enable the implementation of NBS in urban areas. The identified strategies are elaborated in the below section.

2.5.2.1 Collaborative governance

Collaborative governance systems were a recurring theme tackled in the literature (Kabisch et al., 2022; Kabisch et al., 2017; Van Ham & Klimmek, 2017). It is described as structures that include city officers, citizens, the private sector, civil societies and Non-Governmental Organizations (NGO). A collaborative governance structure would allow for a sound distribution of tasks resulting in decreased risk among actors (Wamsler et al., 2020). In addition, the promotion of co-design, co-creation, and co-management are closely tied to the successful implementation of urban NBS for CCA (Wamsler et al., 2020; Puskás et al., 2021; Kabisch et al., 2017). These components and partnerships will create synergies among the governmental and business sectors, as well as between individuals and civic society which will lead to the combination of information, resources, knowledge, and abilities. It follows that a comparable strategy that also contributes to overcoming NBS implementation barriers is minimizing departmental silos. This means structural modifications that encourage collaboration across departments within a city or organization (Kabisch et al., 201 Walsmer et al., 2020).

Additionally, having shared nature-inclusive ambitions are crucial for a successful NBS implementation, and that collective action aggregations can effectively overcome a significant number of barriers especially when governance models and partnerships are collaborative, multisectoral, polycentric and adaptive (Eggermont et al, 2015; De Rooij et al., 2022; Monti, 2020). Furthermore, partnerships between civil societies, local authorities and businesses would be enhanced when grey infrastructure solutions are consciously avoided, administrative burdens are reduced, and incentives are offered (Kabisch et al., 2016). By ensuring such partnerships, many benefits would arise including improved planning since more views are taken into account, enhanced legitimacy since more stakeholders are anchored in the planning and implementation process, promotion of trust, ecological stewardship and social learning leading to enhanced acceptance of NBS due to open discourse (Kabisch et al., 2016).

2.5.2.2 Evidence

Demonstrating proof of the multifaceted benefits urban NBS provide to both society and businesses can pave the way for more successful NBS implementation. Quantifying the environmental, social, and economic advantages of NBS interventions helps build vital awareness and appreciation for these approaches among both citizens and stakeholders (Wamsler et al., 2020).

For instance, research and pilot projects that showcase NBS effectively enhancing community climate resilience, health outcomes, biodiversity, and sustainability can provide credible evidence to convince decision makers of the value of NBS (Kabisch et al., 2016). Similarly, analyses that reveal cost savings, risk reduction and new revenue streams stemming from business adoption of NBS, make a compelling business case for private sector engagement (Kabisch et al., 2016).

Furthermore, actively involving residents in NBS planning and development through participatory processes can avoid potential opposition rooted in uncertainty or skepticism regarding nature-based methods (Wamsler et al., 2020). Co-creation builds constituent buy-in early while raising public understanding of the multifaceted upsides.

Therefore, quantifying proofs and broadly communicating the varied advantages NBS approaches offer cities, communities, and businesses can enable these solutions to overcome barriers rooted in lack of awareness, understanding, and acceptance. Demonstrating the efficacy and worth of working with nature is key to unlocking NBS at scale in urban spaces.

2.5.2.3 Knowledge

Leveraging expertise gained through past urban NBS projects for CCA can pave the way for more successful future NBS deployment. Learning from prior initiatives in terms of what enabled efficacy versus what posed challenges, helps actors apply proven strategies while avoiding previous mistakes when undertaking new interventions (Kabisch et al., 2016; Wamsler et al., 2020). Formally compiled best practices and post-project insights shared across involved firms, agencies, and personnel can accelerate knowledge development in this emergent field (Wamsler et al., 2020).

Establishing centralized platforms, working groups, or stewardship hubs to systematically document and disseminate NBS knowledge enables broader capacity building (Kabisch et al., 2016). As practitioners collectively pool their diverse experiences implementing projects across contexts, they can explain complex processes, refine technical guidelines, and identify adaptive solutions tailored to local priorities (Kabisch et al., 2016).

Furthermore, designating specific change agents responsible for networking between sectors, departments, and partners fosters collaborative mentalities and integrated thinking essential to multifaceted NBS projects. These skilled liaisons actors spanning functions from design to community outreach help bind the interdisciplinary mix of expertise necessitated when working across built and natural systems (Kabisch et al., 2017).

Hence, directly building off previous urban NBS experiences using structured knowledge exchange tools, accelerates technical learning while change agents help bridge disciplinary gaps - both boosting acceptance and ensuring the successful implementation of NBS.

2.5.2.4 Financial

Actors should be prepared to take risks, which requires them to understand that unanticipated expenses and investments might occur (Wamsler et al., 2020). In addition, it is important to remind stakeholders that anything "green" sells and is profitable, therefore it is important to share with targeted actors successful NBS funding stories to motivate them (Kabisch et al., 2016; Wamsler et al., 2020). Furthermore, and as explained by Wamsler et al., (2020), it is essential to outsource for NBS implementation. This is particularly important when it comes to addressing municipal lack of influence on the private market. For example, this can be achieved by providing the public with guidelines for uptaking greening activities on private lands (Wamsler et al., 2020).

Implementing nature-based solutions requires accepting that some financial uncertainty might arise during the implementation process and monitoring phase, and stakeholders must be prepared to handle unanticipated expenses should they emerge over the course of NBS project (Wamsler et al., 2020). As nature-based solutions rely on ecological systems that can demonstrate unexpected fluctuations, additional costs associated with sustaining or replacing ecosystem services could arise (Kabisch et al., 2016). Natural processes often have high inherent variability and according to Eggermont et al. (2015), this means expenditures related to previously unforeseen climate events, migratory impacts, diseases, or other biotic/abiotic factors may become necessary to maintain functioning NBS over long time horizons.

Therefore, actors involved must have reasonable risk tolerance and organizational adaptability to address such unforeseen events through additional budget, workforce, or resources as needed (Wamsler et al. 2020). Developing a committed capacity to handle financial or operational lags can prepare stakeholders to sustain NBS projects despite ecological unpredictability. This builds confidence in selecting natural approaches even facing inherent uncertainties.

The strategies presented above for enabling urban NBS implementation represent key approaches extracted from current academic literature. These strategies have been consolidated into four main themes as highlighted in figure 2 below. This grouping is based on common concepts and target areas that emerged across the analyzed literature focused on strategies for enabling NBS implementation. Together, these four strategic themes synthesize the principle, barrier-targeting mechanisms recommended across scholarly research.

While valuable strategies have emerged around collaborative governance, evidence building, knowledge exchange, and financial preparations to enable nature-based solutions implementation, significant research gaps remain in terms of concrete strategies for urban NBS implementation in the context of CCA with clear emphasis on developing guidelines and strategies for stakeholders that facilitate the implementation process (Kabisch et al., 2022; Dorst et al., 2022; Raška et al., 2022; Cortinovis et al., 2022). The existing literature also predominantly takes a conceptual approach in proposing implementation strategies based on limited case study insights rather than empirical assessment of strategy efficacy across diverse contexts (Davies & Lafortezza, 2019). Quantifying the relative success of specific approaches at overcoming implementation barriers is also lacking (Raška et al., 2022; Cortinovis et al., 2022).

Additionally, the majority of the research has centered on Europe with less representation of strategies tailored to barriers in other regions (Seddon et al., 2022). Developing a global evidence case benchmarking strategy effectiveness against principal barrier themes through comparative analysis, promises more systematic guidance on how cities worldwide can advance impactful NBS deployment given their distinct constraints. The research undertaken in later sections seeks to directly tackle these gaps around comprehensive strategies to overcome barriers by gathering insights from international studies on urban NBS implementation.

Strategies to overcome urban NBS implmentation barriers

A- Collaborative governance:
. Creating and engaging on collaborative governance systems
. Establishing multisector, collaborative, polycentric and adaptive governance models
. Shared goals
. Creative thinking

B- Evidence:
. Highlighting NBS advantages
. Presenting quantified yields
. Awareness

C- Knowledge
. Valorizing and making the most of existing expert knowledge.
. Knowledge sharing

D- Financial
. Willingness to accept and tolerate risk
. Emphasazing demand and value
.Outsourcing

Figure 1: Strategies for NBS Implementation

2.5.3 Relationship between Barriers and Strategies

Understanding the relationship between strategies used to overcome barriers is essential in terms of facilitating a successful NBS implementation. The below framework highlights key linkages that emerge from the academic research between predominant barriers obstructing urban nature-based solutions and corresponding strategic approaches to overcome these challenges.

Table 4. Relationship between barriers and strategies – Literature review

	Barriers	Strategies
Policy	Municipal Policies	• Collaborative Governance
	National Policies	• Collaborative Governance • Change agents to bridge siloes
Knowledge	Development and advancements	• Knowledge exchange platforms
	Performance evidence	• Building evidence from previous projects • Awareness
	Skilled labor and organizational capacity	• Knowledge exchange platforms
Financial	Cost-benefit analysis	• Financial Risk Tolerance
	Demand and Investments	• Outsourcing • Green is the trend.
	Maintenance cost and monitoring	• Financial Risk tolerance • Outsourcing
Collaboration and Engagement	Public acceptance and engagement	• Co-creation process for early engagement • Awareness
	Lack of collaborative governance systems	• Change agents to bridge siloes
	Lack of private sector support and engagement	• Co-creation process for early engagement

While linking barriers to potential solutions through this framework seems logically sound, the simplicity of the framework belies deeper complexities. As Cortinovis et al. (2022) and Seddon et al. (2022) discuss, barriers seldom manifest in isolation and are typically interconnected across financial, policy, knowledge, and engagement domains. Therefore, coherent strategies spanning these spheres are essential rather than disconnected actions. Furthermore, the proposed solution mappings remain grounded more in theory than empirical evidence. The claims made about the potential effectiveness of the strategies lack solid backing. There is no evidence from thorough, systematic evaluations that analyze and compare how well the approaches address barriers across different real-world settings globally.

For instance, the framework proposes "knowledge exchange platforms" as a widely relevant solution tied to multiple barriers like performance evidence gaps and organizational capacity limitations. However, Trell et al. (2019) found knowledge exchange alone insufficient, emphasizing that exchanges must actively involve community participation that embeds local priorities. Similarly, Davies and Lafortezza (2019) argue solutions must align with localized governance and cultural norms to succeed. Therefore, the framework seems overly simplistic. It proposes generalized one-size-fits-all solutions rather than interventions tailored to local contexts.

The suggested connections offer useful foundations. However, additional research through extensive empirical studies across varied global settings can refine these starting points. Specifically, broadly inclusive quantitative analyses that systematically assess real-world strategies effectiveness against barriers can refine current knowledge. Rather than case-limited hypotheses, large-scale comparative evaluations of strategies viability in implementation worldwide promises more concrete guidance on optimal interventions for successful NBS implementation.

CHAPTER 3
RESEARCH METHODOLOGY

A significant gap persists regarding a comprehensive framework matching targeted strategies to address barriers obstructing urban nature-based solutions implementation and advancement globally. While prior literature delineates varied barriers spanning policy, economic, knowledge and collaboration dimensions, studies also fail to empirically examine specific challenges encountered and prioritize key barriers based on tangible evidence from global on-the-ground projects. In addition, there is a lack of clearly defined strategies to overcome NBS implementation barriers globally. While literature acknowledges a list of barriers, recommendations outlining actionable and tailored mechanisms to alleviate impediments remain limited.

To directly tackle these gaps, the following section explains how this study answered the research question, how are barriers to implement urban Nature Based Solutions for Climate Change adaptation overcome?

The methodology of this research employes an extensive comparative case study analysis using documented experiences from implemented urban NBS projects worldwide. By coding barriers and strategies extracted from over 100 case studies, quantitative assessment of encountered frequencies reveals both priority barriers and comprehensive strategies targeted towards a successful NBS implementation. Furthermore, clustering comparative insights across cases and regions provides a robust, grounded foundation to inform coherent actions plans for alleviating implementation challenges. This approach examining global datasets promises more targeted understanding of barrier removal mechanisms for unlocking NBS implementation globally.

3.1 Research design

The research followed a qualitative approach adopting multiple case study research design. A qualitative approach is gathering and evaluating non-numerical data, such as texts and documents in order to better comprehend concepts, views, or experiences. It can be utilized to gain in-depth insights on a topic or to develop new ideas (Shank 2002).

According to Yin (1994), multiple case study research design is an empirical investigation that explores a current phenomenon within its real-life setting, particularly when the boundaries between the environment and the phenomenon are unclear, and it relies on numerous sources and cases of information. Additionally, according to Scharmm (1971, cited in Yin 2014:15), multiple case study research tries "to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result (p. 15)".

This research aimed at investigating the phenomenon (strategies) of overcoming barriers to urban NBS implementation using real-life implemented projects. Exploring multiple case studies allowed for analysis of data both within and across each case, known as cross-case synthesis, which enabled a comprehensive understanding of differences and similarities between the selected case studies and the synthesis of plausible cross case patterns (Yin, 2014). This also allowed for stronger correlation of findings (Yin, 2014). Furthermore, given that multiple case study research was implemented, this allowed the research not only to ensure internal validity of data but also allowed for external validity which led to analytic generalization of data (Yin, 2014)

Case study evidence sources were collected from project reports, third party transcribed interviews, scientific journals, etc.. This means that the research used multiple sources of evidence which allowed the researcher to address a broader range of phenomenal issues and opened the opportunity for triangulation which ensured construct validity (Yin, 2014).

Furthermore, the barriers and strategies identified through the literature synthesis in earlier sections served as a conceptual framework against which to compare the empirical case study findings. Quantitatively assessing the themes evidenced across diverse global cases versus the prevalence put forth in existing research allows for meaningful generalizations. Where alignment exists between published proposals versus documented experiences, strategies and barriers validity strengthens.

Additionally, analyzing the case studies revealed new barriers and strategies that prior literature had not emphasized. These previously overlooked obstacles and enablers offer fresh dimensions beyond existing knowledge. Assessing global case studies ensures increased accuracy by uncovering challenges and solutions directly in action, aligned with real-world examples. Hence, cross tabulating literature-proposed barriers and strategies against those emergent from comparative international implementation assessments will determine the external validity and general viability of existing conceptual models on barriers and strategies. Data processing and analysis are further highlighted in section 4.5 and 4.6.

3.2 Database selection

An initial desk research was completed to identify an initial set of databases relevant to the scope of this research. The desk research resulted in identifying five main databases: JNCC , Climate-ADAPT, NetworkNature, and Nature Based Solution Initiative. In addition, these four databases also include case studies from other smaller databases such as Oppla, Darwini, DevTracker, Equato Initiative, GEF, Green Climate Fund, Nature4Climate…

Table 5. Database Content

Joint Nature Conservation Committee (JNCC)	JNCC database is a UK platform established under the Environmental Protection Act 1990 and reconstituted by the NERC Act 2006. As a statutory advisory body, this public-sector partnership publishes scientific guidance for decision-makers on applying environmental research. This NBS database contains 2,934 climate mitigation and adaptation focused projects. The detailed case studies extract barriers faced and key enabling strategies.
European Platform for Climate Adaptation, Climate-ADAPT	Climate-ADAPT is a partnership platform developed by the European Commission and European Environment Agency (EEA) to assist pan-European climate change adaptation. Launched in 2012, its 114 case studies across EU member countries outline encountered obstacles, lessons learned from failures, and locally replicable best practices.
NetworkNature	Launched in 2017, NetworkNature is an NBS knowledge hub funded by the EU Horizon 2020 program for consolidating applied urban and natural solutions research globally. This expanding open-access resource includes 529 international examples. The documented studies highlight implementation challenges arising and participatory processes with civil society partners that served as corrective actions.

Nature-based Solutions Initiative	The Nature-Based Solutions Initiative portal stems from Oxford's interdisciplinary research program established in 2017 to shape global policy through quantified evidence on NBS efficacy. Alongside academics, this initiative collaborates with development NGOs and public agencies to demonstrate NBS impact. It has compiled 279 cases, largely in developing regions that examine barriers and critical drivers that ultimately achieved sustainable execution.

Overall, the main four databases that were used for the purpose of this research are Climate-ADAPT, JNCC, NetworkNature and Nature-Based Solution Initiative. These four databases include 3,856 case studies.

3.3 Assessment of barriers and strategies mentioned in the database.

Strategies and barriers extracted from the global case studies were systematically checked to reveal real-world frequencies and importance beyond theoretical proposals. Quantitatively compiling which implementation challenges or enabling mechanisms arise most prevalently grounds academic hypotheses in empirical evidence.

Additionally, inductive coding surfaced innovative strategies not covered in existing literature. These "emergent" strategies organically respond to on-the-ground realities, complementing top-down perspectives. For instance, participatory budgeting directly empowers marginalized communities to allocate investments, counteracting exclusionary planning processes. Such collaborative solutions directly tackle equity barriers by empowering communities excluded from conventional top-down planning.

Hence, quantifying case study strategies against literature themes combined with inductively uncovering grounded innovations synthesizes theoretical perspectives with on-the-ground realities. The methodology is covered in depth in sub-sections 4.6, 4.7 and 4.8.

3.4 Case study selection

The research followed a criterion sampling strategy (Yin, 2014) to select global NBS case studies implemented for CCA. Criterion sampling involves the selection of a sample based on some pre-established criteria (Yin, 2014).

The case studies that were included are not limited to one geographical location, but rather global case studies were selected. This allowed for a larger and a more comprehensive understanding of NBS implementation barriers which in turn will result in generalized implementation strategies for NBS that can be applied in different contexts.

The focus pool of case studies was developed based on the following set of criteria that serve the purpose of the main research question:

Table 6. Inclusion exclusion criteria

Criteria	**Reason**
Case study is a fully implemented NBS project	It is possible that actors involved in a newly initiated NBS project might not face barriers that are directly related to hindering the implementation process of the NBS project but rather barriers related to the fact the project is yet to start which might dilute the relevant data pertaining towards the research question.
NBS project is implemented for Climate Change adaptation. Check background and abstract section for words such as climate change, climate change adaptation	Scope of research question
Case study includes reports, articles and interviews about drivers and/or barriers	Data coding
Case study implemented in an urban context	Scope of research question

Authorship of reports, articles and journals	Data validity
The pool of the case studies includes divers cases across various geographic contexts	Scope of research question

Case studies in which climate change regulation and adaptation are inferred as a benefit rather than a motivator were omitted. The inclusion of such examples may expose the sample to too many cases, diluting it with case studies of very limited CC relevance.

As a result, non-climate change related NBS such as urban gardens, beekeeping initiatives, parks, and other green places that show non-climate change related motivators such as education and/or social wellness, access to green spaces, or air quality improvement were be eliminated.

Additionally, all case studies that do not fit within the mentioned conditions above were excluded.

It is important to note that some case studies within the database did not include a comprehensive report about the applied NBS intervention, thus additional research was carried out to gather missing information. The name of the intervention as stated in the database along with the country name was used to carry out the search. In this case, reliable sources were checked i.e., government websites, consultancy or engineering/architect firms involved in the project and peer reviewed journals, for further information.

3.5 Developed pool of case studies for coding

An extensive list of keywords was used to systematically search the databases, including: "climate change", "climate change adaptation", "urban climate adaptation", "urban heat islands", "extreme weather", "floods", "drought", "heatwaves", "nature-based solutions", "green infrastructure", "urban forests", "parks", "wetlands", "low impact development", and other related terms. This returned an initial extensive list from the thousands of documented case studies those potentially dealing with climate adaptation challenges and nature-based approaches in cities.

Abstracts were then checked for each result to confirm relevance. Only cases clearly focused on applying nature-based strategies to build urban resilience and adaptive capacity in the face of identified climate threats underwent full review. Common threats highlighted included rising temperatures, heat waves, drought, extreme rainfall and inland/coastal flooding.

Selected cases then went through careful screening to determine eligibility for in-depth analysis. Each case background was reviewed to validate climate adaptation was a primary motivator driving nature-based solution adoption rather than an ancillary benefit. Current or projected climate hazards had to represent explicit priorities the project aimed to adapt through ecosystem approaches. Cases vaguely referencing climate issues without clearly targeted adaptation goals to address warming, heat, flood or similar threats were deemed insufficient and excluded no matter the strength of remaining documentation.

Additionally, each case study needed to entail a fully implemented NBS project already operational within an urban area rather than proposals or pilots still under analysis. The projects could range in size and budget but had to be on-the-ground interventions in neighborhoods, districts or cities actively providing ecosystem services to reduce targeted climate change impacts versus hypothetical or planned initiatives still pending execution.

Moreover, case study reports, evaluations or interview transcripts had to provide adequate detailed elaboration on implementation challenges and successes. Documents vaguely noting barriers during planning, design or construction without extracted specifics on critical factors enabling project delivery were eliminated. Priority was given to evidence with explicit emphasis highlighting key obstacles arising and strategies used to overcome setbacks during execution. This allowed for sufficient content richness to enable comparative coding and quantification on drivers versus impediments influencing outcomes.

Through this extensive search and rigorous screening process, the initial pool of 3,856 case studies documented across the databases was systematically narrowed down to 103 qualifying examples for in-depth analysis.

3.6 Case Study Data Extraction

Data extraction or collection is defined as the process of gathering information on various variables of interest in a systematic way that enables the researcher to answer a posed research question, evaluate outcomes and test hypothesis (Creswell, 2009). Relevant descriptive and nominal data such as words and sentences reflecting on barriers or strategies for NBS implementation were extracted from the selected reports, interviews, journals and coded for further analysis (Yin, 1994). The full documents were imported into Nvivo 14 pro, then the whole document was surveyed and read in detail and relevant sentences addressing NBS implementation were extracted, using the codes function in the software. After all the documents were imported and relevant data was extracted, the node function was used to group data into overlapping themes. Further details about extraction and coding process are presented in section 3.8 below.

3.6.1 Transcribed third-party interviews

Various case studies include transcribed interviews conducted with key actors managing the NBS project. The interviews are individual face to face interviews following a semi-structured format and including questions about drivers and barriers for NBS implementation. Relevant data was extracted by going through the whole transcribed interview and highlighting relevant ideas.

3.6.2 Document review

Furthermore, in this research information was extracted from different documents. Guba (1985) explains that a document is "any written or recorded material", this can include, journals, scientific articles, archival records, etc. Extracted information was considered alongside other forms of extracted data. All documents were thoroughly read and statements covering barriers and/or strategies were identified.

3.7 Data processing

Data processing is when computed operations are carried out on data to classify them, this will lead to changing the form that the data is in, and making the data easier to view (Yin, 2014). For this study, the literature review section played a major role in demarcating and processing the extracted data from the case studies.

When all the case studies were coded and relevant sentences were extracted, the data was grouped following the theoretical propositions technique. In this technique, extracted data from case studies was grouped and categorized based on the barriers and strategies identified in the literature section (Yin, 2014). Therefore, data was grouped based on the schematics developed in the literature section.

3.8 Data Analysis

Extracted data from transcribed interviews and documents was coded using NVivo 14 pro, which is a computer-assisted qualitative data analysis software (CAQDAS). This software is considered as one of the most reliable tools for qualitative data analysis (Best, 2022). Coded data was analyzed using both pattern matching along with cross-case synthesis analysis techniques.

In pattern matching, “analysis of case study data occurs by comparing or matching the pattern within the collected data with a pattern defined prior to data collection (through literature review for example)” (Yin, 2014)

In cross case synthesis a compilation of data from multiple case studies was undertaken after each individual case has been examined and patterns across cases were observed (Yin, 2014)

Conducting pattern matching and cross case study analysis ensures internal validity of data and allows for external validity of data and strategies (Yin, 2014).

Therefore, the barriers identified in the literature section served as a basis for the coding scheme. Each coded data extracted from the case studies was allocated to one or several of the barriers identified in the literature. Furthermore, extracted data from the cases were compared across cases as well.

A similar coding pattern was applied in the case of strategies. Additionally, codes containing statements about strategies to overcome a barrier were analyzed to gain insights into which strategy is used to overcome which barrier.

In addition, data that did not fit within the predefined literature section were grouped together and were considered as emergent strategies or emergent barriers.

It should be noted that the coded data and analyzing the findings entailed a reiterative process, in which the researcher continuously interpreted and made meaningful sense of the data.

Each case study report was coded using NVivo 14 pro. The thematic overview of the barriers served as a basis for the coding scheme. Coded barriers were stored then grouped based on the categories identified in the literature. The new barriers were grouped separately resulting in new categories of barriers. The coding process resulted in a total of 2,450codes, each of which was allocated to one or several of the 32 sub-barriers identified through the literature review, which they fall under the 11 predefined barrier categories and the four central general themes (Check Appendix I for clarification regarding the coding process).

To obtain insight into the strategies employed and their relevance to particular types of urban NBS interventions, the codes containing statements relating to strategies to overcome a perceived barrier were compared. A total of 3,938 codes resulted from the coding process. The contrasts and similarities across the cases were investigated. There were 22 unique strategies discovered once any overlap was ruled out. The four themes of strategies discovered through the literature review were then compared to these defined emergent strategies.

After coding the barrier and strategies and grouping them, the relationship function in NVivo 14 pro was used to highlight the relationship between the barriers and the related strategies deployed to overcome that barrier.

In addition, 4 predefined categorical variables were attributed and assigned to each case study. These variables define the context of the case studies. The following categorical variables were used, continent (with 4 variables), type of NBS intervention (with 6 variables), scale (with 4 variables), climate change impact (with 7 variables). These variables were used when assessing the barriers and strategies across contexts. (refer to appendix III for a comprehensive list of the categorical variables).

3.9 Reliability and validity of data

The case study analysis extracted insights from a mix of source materials including database records, academic papers, technical reports, and governmental documents.

Consolidating evidence from these multiple inputs enabled triangulation - examining projects from different lenses to facilitate robust understanding. For instance, brief database overviews were supplemented by detailed peer-reviewed studies and design specifications (Yin, 2014).

Ultimately, triangulating diverse documentation on each case aims to validate results through cross-verification between sources. Rather than a narrow singular perspective, considering complementary inputs bolsters confidence in research legitimacy. It also produces multifaceted knowledge on the complex blend of barriers and enablers influencing project outcomes (Yin, 2014).

Additionally, internal validity was highly satisfied given that data across cases was compared and also matched to the literature (Yin, 2014). In addition, given that data from global case studies was collected this allowed for external validity and analytic generalization of data (Yin, 2014).

However, it is important to acknowledge that it is impossible to duplicate a certain social setting given that it is constantly changing (Nosek et al., 2022). This directly applies to the research in question since barriers and strategies might evolve and change overtime. However, future research can follow the steps posited in this study to identify future barriers and develop upcoming strategies.

CHAPTER 4

RESULTS

The results are into 4 sections. First, the case studies are briefly presented, second, the identified barriers are presented along with the frequency of encountering each barrier. Third, the identified strategies are showcased and discussed in addition to the frequency of employing each strategy. Finally, a relationship between the strategies and barriers was defined.

4.1 Overview

This section presents the findings from the systematic analysis of the 103 case studies selected for this review. The case study analysis examines patterns and trends related to implementation barriers, enabling strategies, scale, geography, intervention types, and climate change adaptation impacts.

4.1.1 Characterization of selected Case Studies for Assessment

After reviewing the four databases, 103 case studies were selected after employing the inclusion exclusion criteria. Among the 103 cases, 45 are located within Europe, 22 cases in America, also 22 cases in Asia and 14 cases in Africa. It was expected to have the highest number of case studies within Europe because the European Union is the most active when it comes to NBS in general (Debele et al., 2023). The EU has funded extensive research on NBS through initiatives like the Horizon 2020 program. This research has advanced the understanding of how to design, implement, and manage NBS projects. The EU has also supported numerous demonstrator NBS, establishing itself as a global leader in this emerging field. Refer to Appendix II for the full list of case studies. In addition, the tables below give an overview of the distribution of the sample case study across scale, the types of NBS intervention and the addressed CCA impact. It is important to note that the highlighted CCA impact in the table below presents the major impact addressed, however the intervention can also contribute to other CCA impacts. In addition, some of the green roofs/ green wall interventions were also implemented with a secondary goal of enhancing climate resilient urban agriculture and roof gardens. Furthermore, the green corridors interventions included case studies addressing the implementation of street trees, green belts, pocket forests. Blue green infrastructure includes bioswales, rain gardens, green streets, mangrove restoration and/or watershed restoration, river restoration and constructed wetlands.

Table 7. Overview of case studies: Scale, CCA impact and Type of Intervention

Type of Intervention	
Blue green infrastructure	49
Green corridors	11
Green Roofs / Green walls	16
Urban forest	12
Urban Park	15
Grand Total	**103**

CCA focus	
Biodiversity	9
Heat	27
Heat and Biodiversity	16
Heat and Water	11
Water	40
Grand Total	**103**

Scale across Continents	
City	**41**
Africa	2
America	11
Asia	7
Europe	21
Neighborhood	**22**
Africa	6
America	4
Asia	7
Europe	5
Regional	**30**
Africa	6
America	6
Asia	8
Europe	10
Site	**10**
America	1
Europe	9
Grand Total	**103**

4.1.2 Methodological Note on Barriers and Strategies Percentages

The subsequent sections present graphs depicting the percentage of case studies that addressed various themes of barriers or implementation strategies. It is important to note that these percentage values were calculated based on the number of cases that discussed barriers or strategies, rather than the total number of cases reviewed.

Out of the 103 total cases reviewed, 89 cases addressed implementation barriers, while 99 cases discussed implementation strategies. The majority of cases examined both barriers and strategies. However, some cases focused exclusively on either barriers or strategies.

For example, the percentage of cases discussing policy barriers was calculated based on only the 89 cases that examined implementation barriers. This percentage does not reflect the total pool of 103 cases. Using the total number of 103 cases would underestimate the proportion of barrier cases focused on policy issues.

Similarly, the percentages for strategy themes were based only on the 99 cases that addressed implementation strategies. Calculating percentages from this targeted pool of strategy cases, rather than the full 103 cases, provides a more accurate representation of which strategies were most commonly discussed.

Maintaining this analytical distinction allows for a more precise understanding of which barriers and which strategies were most prevalent across the case studies that examined those specific topics. In this way, the subsequent percentage values provide targeted insight into relative barrier and strategy trends within their respective pools of barrier and strategy cases.

4.2 Barriers to NBS implementation

Figure 1 in section 2.5.1 highlights the barriers, identified from the literature review, that were expected to hinder the implementation of NBS in urban areas for CCA. These barriers were compliant with the findings of this research. However, a new sub-theme was identified which is the timeline of the project. This idea was mentioned in the literature review but was better articulated through the coding and analysis of data which lead to the creation of this new subtheme. In addition, based on the coding and analysis process, the frequency of encountering each barrier was developed as shown in figure 3 below. Identifying the frequency of barriers across NBS cases helps prioritize the most critical challenges to address. Barriers cited consistently in many projects likely indicate systemic, widespread. These recurring barriers should be priority areas for reform efforts. Therefore, tracking frequency identifies the main points hindering NBS adoption on a broad scale. A total of 89 case studies from the 103 identified cases included barriers. As shown in figure 3 below, 65 (73%) out of the 89 cases perceived barriers related to policy. 64 (72%) of the case studies perceived barriers related to Knowledge. 63 (71%) of the case studies perceived barriers related to Collaboration and engagement, and 43 (48%) of the case studies reported financial barriers. The most encountered barriers are mainly related to Collaboration and Engagement, Knowledge, and Policy barriers. Financial barriers were also encountered when implementing NBS projects but not as pronounced compared to the other 3 themes.

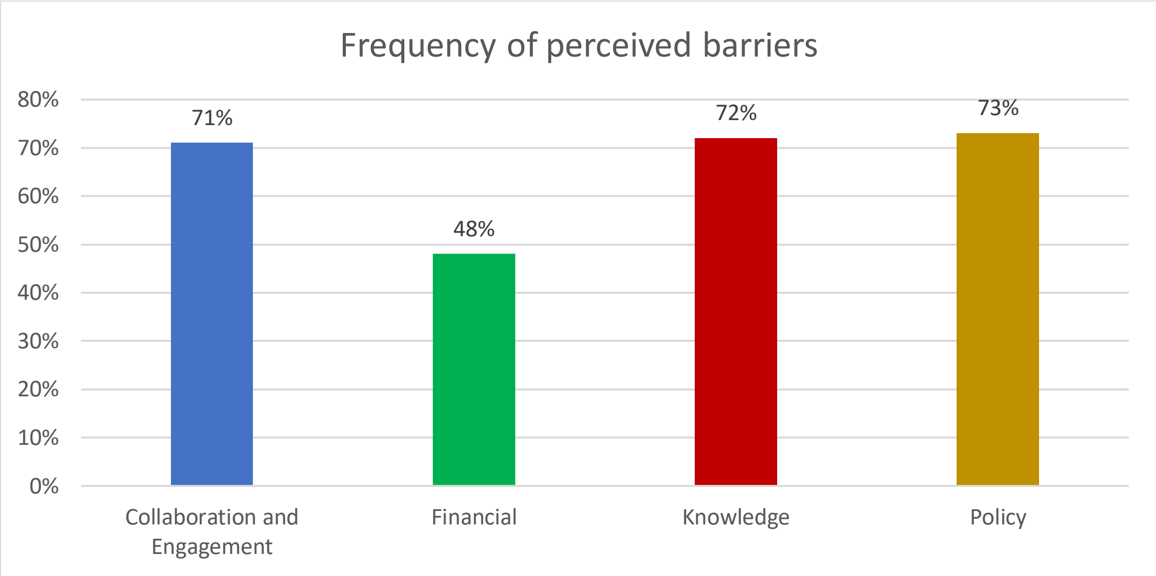


Figure 2. Frequency of perceived barriers

The results show that the most frequent general theme is policy mentioned in 65 (73%) case studies with 654 statements, while the least mentioned is financial barriers mentioned in only 43 (48%) cases with 377 statements. Table 5 shows the results for the high-level categories from highest to lowest.

Table 8. Number of coded cases and sentences - barriers

Type	Files	References
Policy	65 (73%)	654
Knowledge	64 (72%)	793
Collaboration and Engagement	63 (71%)	626
Financial	43 (48%)	377

Figure 4 below depicts the frequency of specific barriers across the case studies that mentioned the theme under study. Interestingly, a small number of case studies addressed the barriers related to Skilled Labor and Organizational Capacities, Demand and Investment and Lack of private Sector support and engagement, however, these barriers according to the literature review were perceived as major barriers hampering the implementation of NBS. This idea is further highlighted in the discussion - section 5.1.

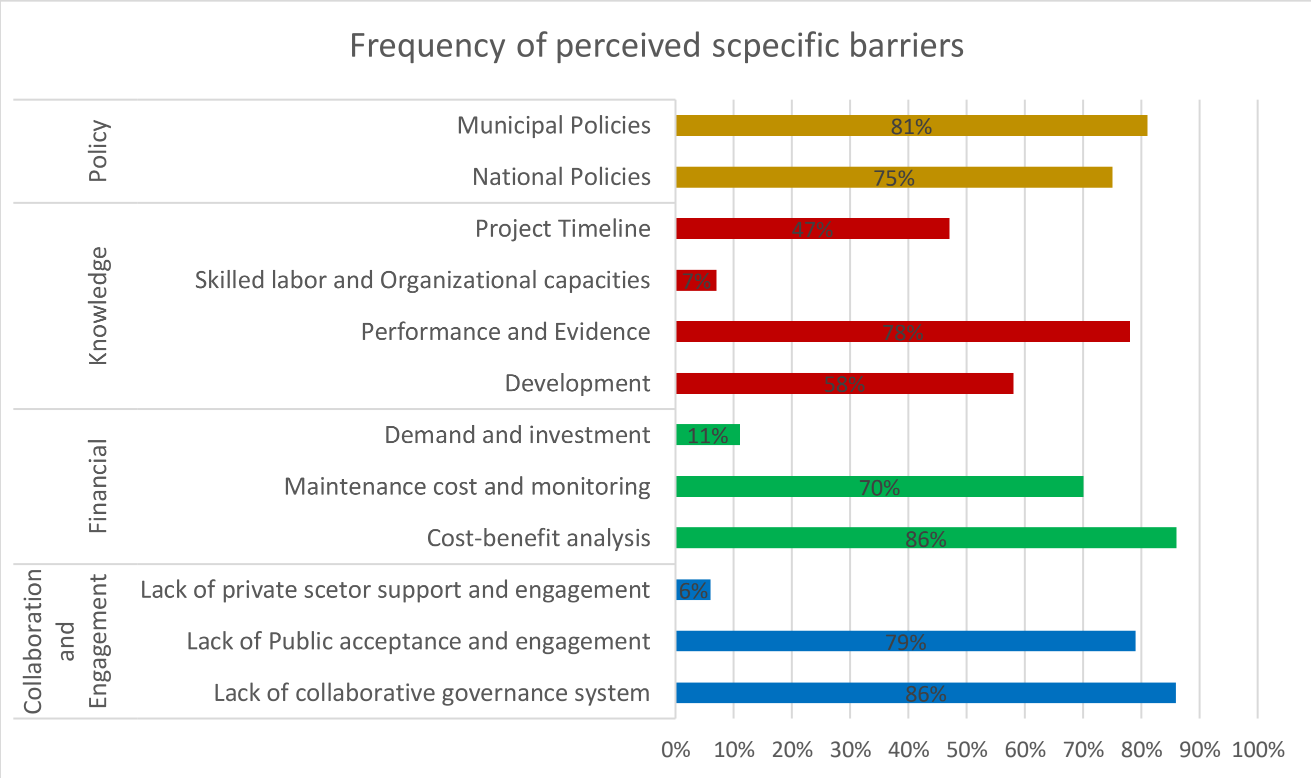


Figure 3. Frequency of perceived specific barriers

In addition, table 6 below shows the results for the specific barriers falling under the above-mentioned general themes from highest to lowest. Under the most frequent general theme – Policy – the most common specific sub-theme is municipal policies mentioned in 52 (80%) out of the total 65 cases with 347 statements, while the least mentioned is Demand and Investment which falls under the least frequent general theme – Financial – and is addressed in 5 (11%) out of the total 43 case studies with 45 statements.

Table 9. Number of coded cases and sentences – barriers sub-themes

Theme	Sub-theme	Files	References
Policy (65 cases)	Municipal Policies	52 (81%)	347
	National policies	49 (75%)	307
Knowledge (64 cases)	Performance and Evidence	50 (78%)	312
	Development	37 (58%)	232
	Project Timeline	30 (47%)	241
	Skilled labor and Organizational capacities	4 (7%)	8
Collaboration and Engagement (63 cases)	Lack of collaborative governance system	54 (86%)	139
	Lack of Public acceptance and engagement	50 (79%)	459
	Lack of private sector support and engagement	4 (6%)	28
Financial (43 cases)	Cost-benefit analysis	37 (86%)	132
	Maintenance cost and monitoring	30 (70%)	200
	Demand and investment	5 (11%)	45

The number of cases reporting a particular barrier should not be equated to the barrier's actual influence or impact in hindering NBS uptake. Just because a barrier is perceived across many cases does not necessarily mean it is most severely obstructing NBS implementation. This will be addressed further in the discussion.

In addition, for the full detail about which case study addressed which barrier refer to the Appendix IV.

4.2.1 Policy Barriers

In fact, municipal policies are deemed as a major barrier for NBS implementation. It is explained that usually municipal policies prioritize different objectives over NBS. It was explained in the case studies that several interests clashed where objectives related to urban densification and energy efficiency are prioritized over NBS.

"… the city's development guidelines emphasized housing units per area and building energy performance over considerations of green space and natural features."

(Warsaw Green Network, 2015, p. 49)

However, actors in the case studies acknowledged that NBS and grey infrastructure that serve these purposes go hand in hand and they should be both included when implementing any project. In addition, municipal handbooks create a restrictive factor hampering NBS uptake in public places. Outdated standards fail to provide appropriate design specifications for NBS elements. Rules on underground utilities or maintenance access restrict green interventions. For example, in *Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals* (2017) case study it was explained that large pipes and underground cables restricted the use of large trees, in addition requirements related to the width of the road that suits the comfort of municipal maintenance negatively affects the required number of street trees to achieve certain temperature reduction levels.

National policies also play a role in hindering NBS implementation. National Building Decrees and requirements favor grey infrastructure over NBS interventions even if they are considered as an excellent alternative in a certain case.

"In our recent project, we struggled with the national building codes that really make it difficult to integrate nature-based solutions. The decrees emphasize traditional hard infrastructure approaches like pipes and concrete channels. Even though green infrastructure could achieve the same goal more sustainably, the official requirements favor grey solutions over nature-based ones. The codes and standards are stuck in the past and just aren't set up to properly value or allow NBS."

(Interview section from the case study Integrated Development of the Hatirjheel Area, 2018, p.37)

4.2.2 Collaboration and Engagement

Limited collaborative governance and citizen engagement are major barriers. In fact, citizens and as explained through the literature review, prefer their own comfort, and display the NIMBYISM Syndrome (Dorst, 2021). In addition, it seems that stakeholders have a negative perception towards citizen engagement. However, such perceptions are based solely on assumptions rather than on previous experiences.

"... assume citizens will oppose any NBS plans so they are not engaged in any meaningful dialogue from the start."

(Building coastal resilience for Muanda's communities, 2022, p.129)

In addition, limited collaborative governance marked by siloed mentalities also impedes the successful implementation of NBS projects. This segregation across departments also amplifies other barriers such as knowledge and policy barriers.

"... different departments tend to operate in silos with little coordination. The transportation department pushes its own agenda without considering impacts on green space."

(Catchment management approach to flash flood risks in Glasgow, 2011, p. 33)

4.2.3 Knowledge Barriers

Another dominant barrier is related to knowledge. In most of the cases, evidence of NBS performance was perceived as a major barrier hampering urban NBS uptake. It was explained that stakeholders find it hard to showcase the multidimensional benefits of NBS. This is mainly attributed to the lack of methodologies or calculations approaches accounting for the multifaceted aspect of NBS, particularly when it comes to the social factor. In fact, the Green Urban Infrastructure in the municipality of Beira case study emphasized the following: *"This showed the difficulty of quantifying NBS multidimensional benefits for stakeholders. With no tools to holistically quantify the range of social, environmental and economic benefits, practitioners struggled to build an effective case and gain buy-in"* (2015, p.27). Furthermore, most of the case studies highlighted the idea that reluctance from organizations such as municipalities and governmental bodies against NBS implementation is common, and this behavior is defended by the idea that organizational support is only for work or initiatives with "proven" practices (Nyandungu Wetland Eco- Park, 2021).

Barriers for NBS development were also common. Existing engineering and architectural styles and methods are usually perceived as unsuitable for nature inclusive designs. In fact, limited knowledge seemed to exist when it comes to green-inclusive alternatives that would still be compliant with exiting grey design structures and typologies. It was also emphasized in Chulalongkorn Centenary Park case study (2017, p. 12) that "*biomimicry in sustainable urban development projects is still in its immature stages of development*".

A new emergent barrier was discovered which is the project timeline. It refers to the specific duration or period allocated for project planning, implementation, and completion. It refers to the established timeline within which all project activities, such as identifying appropriate NBS interventions, acquiring funding, engaging stakeholders, carrying out construction and monitoring, need to be accomplished. A project timeline is essentially a schedule that includes critical milestones and deadlines for the project's various phases. It is essential in project management because it ensures that the project continues on track, that resources are used properly, and that objectives are completed within the timeframe provided. A rigid or unduly constricted project timetable, on the other hand, might represent a barrier in the context of NBS implementation for climate adaptation if it does not allow for the necessary flexibility and adaptation to face evolving issues and changing climatic conditions. When dealing with project timelines in this context, it is vital to balance the urgency of climate action with the necessity for extensive planning and implementation.

"The need to balance urgency and extensive planning when implementing NBS. While climate change necessitates swift action, proper phased implementation was required for long-term success. The tension between acting urgently and diligent preparation had to be navigated."

(Greenbelt of Nur-Sultan City, 2017, p.42)

4.2.4 Financial Barriers

Maintenance cost and monitoring and cost benefit analysis mainly impacted NBS implementation. Private sector engagement was not perceived as a major barrier. This idea is further highlighted in section 6.1.

The idea that the cost of implementing NBS projects is high and does not increase "sales" prices was also perceived in the case studies as mentioned in the literature review.

"... challenges in adopting NBS due to high initial investment costs without sufficient potential to increase sale prices and offset expenses ...The financial analysis indicated the long-term returns did not justify the immediate costs."

(Brasília Serrinha do Paranoá waters project, 2019, p. 41)

However, it is important to keep in mind that the benefits of NBS are not only limited to financial aspects but include social and environmental benefits. Hence when assessing the cost of NBS, it is important to account for its multidimensional aspect and benefits and not only economic benefits.

4.3 Strategies for NBS implementation to overcome barriers.

While the barriers extracted from the case studies mostly marches the findings from the literature review, several strategies were uncovered while coding and analyzing the case studies. The thematic below summaries the identified strategies and the sub-themes in each strategy based on the coded themes.

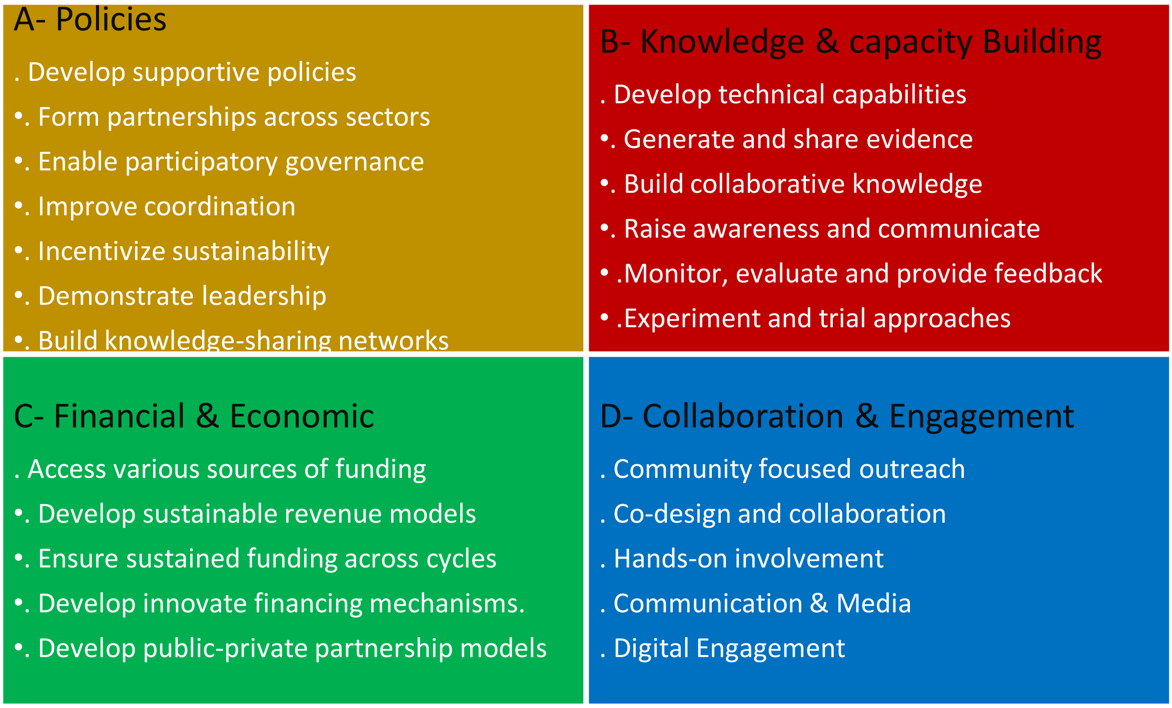


Figure 4. Thematic overview of the aggregated strategies from the case studies

Based on the coding and analysis process, the frequency of employing a certain strategy was developed as shown in figure 6 below. This figure explains the frequency and type of perceived barrier per case study. A total of 99 case studies from the 103 identified cases discussed possible strategies for NBS implementation to overcome barriers.

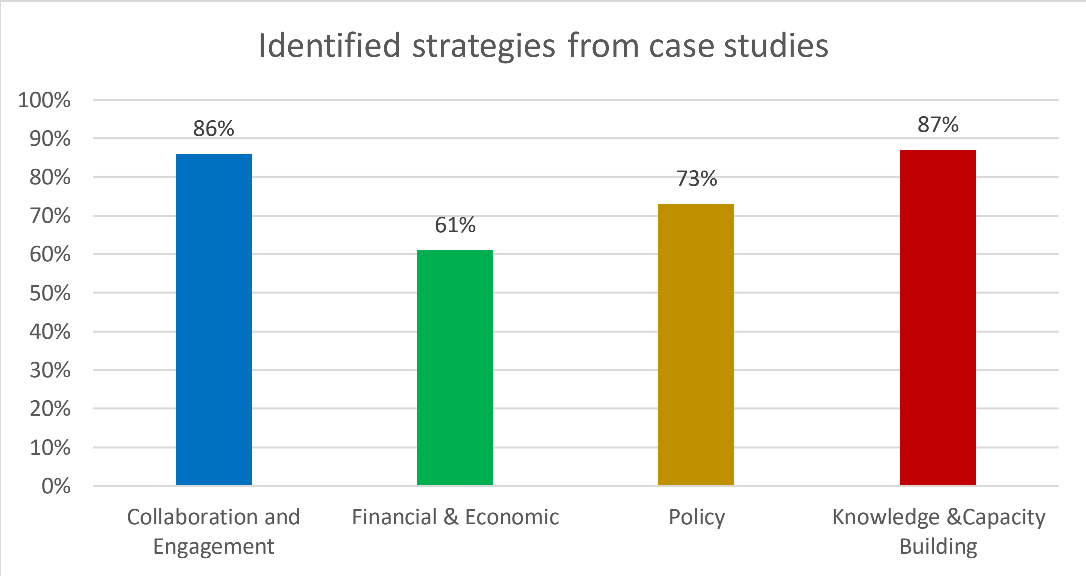


Figure 5. Frequency of the identified strategies

The results show that the most frequent general theme is Knowledge & Capacity Building mentioned in 86 (87%) case studies with 1377 statements, while the least mentioned is financial barriers mentioned in only 61 (61%) cases with 434 statements. Table 7 shows the results for the high-level categories from highest to lowest.

Table 10. Number of coded cases and sentences - strategies

Type	Files	References
Knowledge & Capacity Building	86 (87%)	1377
Collaboration and Engagement	85 (86%)	1369
Policy	72 (73%)	815
Financial & Economic	61 (61%)	434

Figure 8 below depicts the frequency of specific sub-strategies across the case studies that mentioned the general strategy theme.

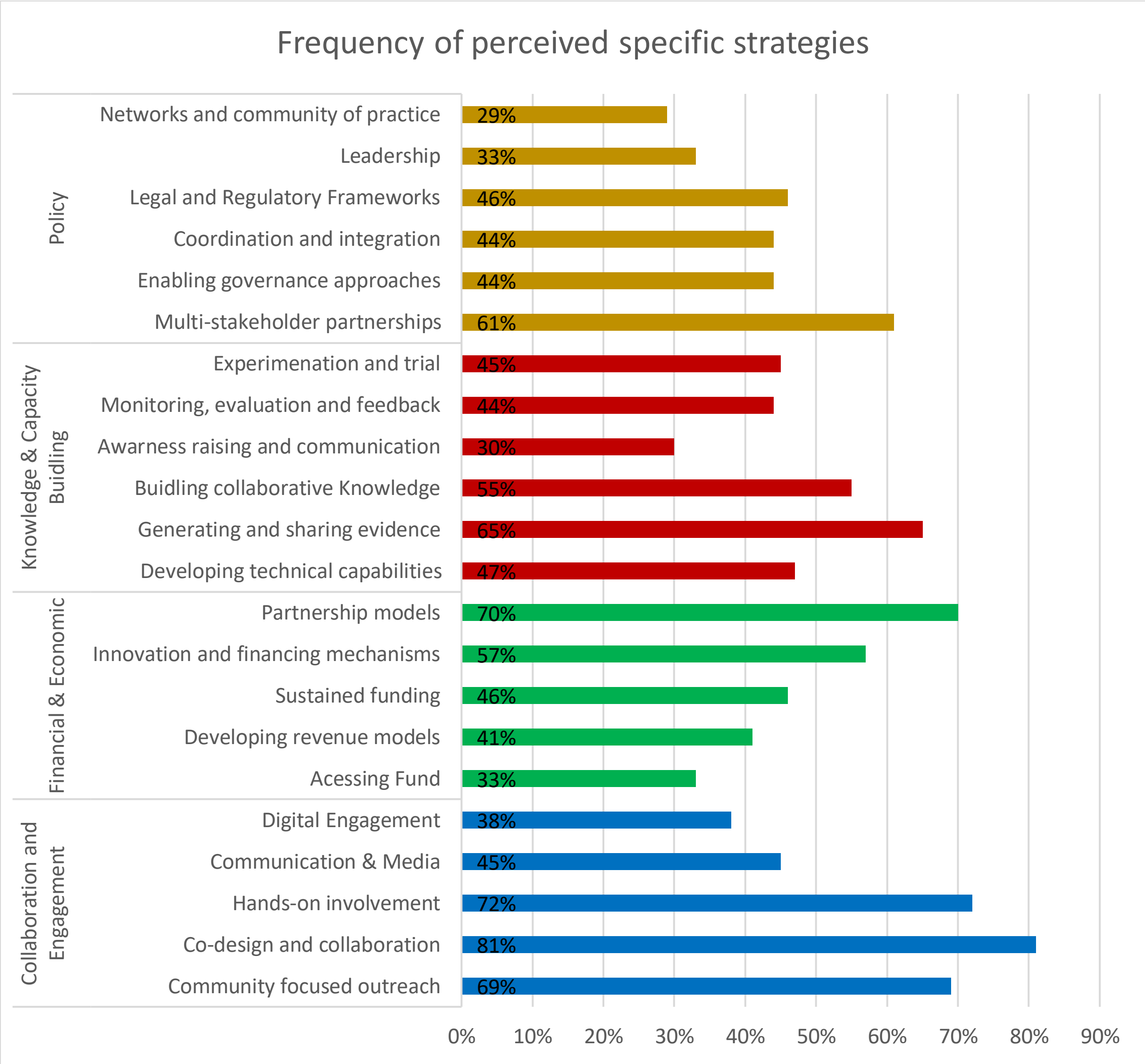


Figure 6. Frequency of perceived specific strategies

In addition, table 8 below shows the results for the specific strategies falling under the above-mentioned general themes from highest to lowest. Under the most frequent general theme – Knowledge & Capacity Building – the most common specific sub-theme is Generating and sharing evidence mentioned in 56 (65%) out of the total 86 cases with 429 statements, while the least mentioned is Accessing Fund which falls under the least frequent general theme – Financial & Economic – and is addressed in 20 (33%) out of the total 61 case studies with 45 statements.

Table 11. Number of coded cases and sentences – strategies sub-themes

Theme	Sub-theme	Files	References
Knowledge & Capacity Building (86 cases)	Generating and sharing evidence	56 (65%)	429
	Building collaborative Knowledge	47 (55%)	301
	Developing technical capabilities	40 (47%)	136
	Experimentation and trial	39 (45%)	242
	Monitoring, evaluation and feedback	38 (44%)	183
	Awareness raising and communication	26 (30%)	86
Collaboration and Engagement (85 cases)	Co-design and collaboration	69 (81%)	626
	Hands-on involvement	61 (72%)	312
	Community focused outreach	59 (69%)	250
	Communication & Media	38 (45%)	96
	Digital Engagement	32 (38%)	85
Policy (72 cases)	Multi-stakeholder partnerships	44 (61%)	187
	Legal and Regulatory Frameworks	33 (46%)	140
	Enabling governance approaches	32 (44%)	132
	Coordination and integration	32 (44%)	115
	Leadership	24 (33%)	109
	Networks and community of practice	21 (29%)	75
Financial & Economic (61 cases)	Partnership models	43 (70%)	151
	Innovation and financing mechanisms	35 (57%)	113
	Sustained funding	28 (46%)	78
	Developing revenue models	25 (41%)	47
	Accessing Fund	20 (33%)	45

For the full detail about which case study addressed which strategy refer to the Appendix V.

4.3.1 Policy

In this section, the identified themes of strategies and their corresponding subthemes are explained.

- Multi-stakeholder partnerships

Cross-sectoral partnerships help overcome silos that impede NBS implementation. By combining government, private, NGO, community, and academic partners, synergies emerge from pooled resources, shared costs, diverse expertise, and coordinated efforts under a shared vision. Partnerships expand capacity beyond any single organization and foster co-ownership. Furthermore, municipal governments can facilitate partnerships through agreements, committees, and joint NBS strategies. In fact, these ideas where particularly discussed in depth in the Green Urban Infrastructure in the municipality of Beira case (2020, p.18) study where it was emphasized that "*By bringing together partners from different sectors, our collaborative governance model created powerful synergies. With diverse organizations pooling financial resources, we could share costs and risks. Combining our distinct expertise allowed for more innovative, integrated solutions. And coordinating across sectors enabled alignment under a unified vision. Working across institutional silos was crucial to overcoming barriers and seizing opportunities*."

Furthermore, co-creation process was also emphasized across the cases. This process actively engages diverse stakeholders, including marginalized groups, in NBS design, implementation, and maintenance. This builds trust, shared understanding, and contextual solutions meeting multiple needs. Co-creation taps localized knowledge, integrates priorities, and fosters joint ownership. While time-intensive, it leads to more equitable, legitimate NBS.

"... co-creation builds trust and inclusive solutions. Engaging community members, especially marginalized groups, from the start led to context specific NBS with broader legitimacy, despite requiring more time upfront."

(Integrated Development of the Hatirjheel Area, 2015, p. 24)

- Enabling governance approaches

Participatory governance models and polycentric, multi-level governance approaches can empower local communities and lower-level authorities through participatory planning and budgeting for NBS.

"Multi-level governance that links top-down support with bottom-up engagement provides an avenue through which local communities can influence planning processes. Participatory decision-making and decentralized governance have been associated with improved satisfaction with final plans and perceived legitimacy of NBS implementation processes."

(Sustaining biodiversity, livelihoods, and culture in PNG's montane forests, 2019, p. 26)

This gives those most directly impacted by NBS greater influence over localized decision making and priorities. Participatory governance builds capabilities and legitimacy for community driven NBS that reflect native assets and needs. It requires investment in public forums, capacity building, and devolution of planning resources and authority. Benefits include tapping into local knowledge, enhancing buy-in, and developing advocates for sustaining NBS.

"Involving local stakeholders through participatory planning and governance can help incorporate valuable local and traditional knowledge into NBS projects. It enhances local buy-in and acceptance of NBS interventions. Over time, engaged stakeholders can become advocates for implemented NBS and play a role in sustaining interventions."

(Urban stormwater management in Augustenborg, Malmö, 2012, p.54)

Another important approach that was emphasized across the cases is adaptive governance frameworks. In fact, given the complexities and uncertainties inherent in NBS, collaborative governance structures must incorporate flexibility to allow for learning and adjustments over time as conditions evolve. Adaptive approaches involve regular monitoring, feedback loops, and iterative cycles of planning, implementation, and revision. These ideas were further elaborated in the Basel, Switzerland case study where they adopted an adaptive governance approach for implementing green roofs as an NBS. They started with small pilot projects that were rigorously monitored. Based on learnings, they adjusted subsidy programs and regulations to scale up green roof deployment. Ongoing monitoring and stakeholder forums enabled further adaptations over time as conditions changed. This flexible, experimental approach was critical in managing uncertainties (Green roofs in Basel, Switzerland - combining mitigation and adaptation measures, 2017)

Therefore, such approach enables course corrections and scaling up of successful NBS strategies while discontinuing those less effective. Adaptive governance requires openness to experimentation, diverse participation, and integrating knowledge into decisions.

- Coordination and integration

In addition, centralized coordination units focused on NBS can help overcome fragmented governance. These units provide expertise to streamline processes, align policies and incentives, and foster enabling conditions for integrated NBS across government agencies. They coordinate activities like asset mapping, planning, funding, capacity building, project pipelines, and monitoring to ensure agencies work cohesively towards NBS goals. The city of Toledo in Ohio adopted this strategy when implementing their NBS project. The city established a Green Infrastructure Maintenance Program within the Water Department to coordinate green stormwater infrastructure across city agencies. This unit develops maintenance plans, trains personnel, generates project funding, and manages assets tracking and monitoring. Having a centralized team has allowed Toledo to maintain existing NBS more efficiently and expand new projects by coordinating planning, funding, and implementation across the Roads, Parks, Transportation, and other departments. The centralized expertise and coordination have been critical in scaling up green infrastructure to meet the city's goals (Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio, 2022)

- Legal and regulatory frameworks

Another important strategy to overcome NBS implementation barriers is to assess regulations across government levels to identify problematic policies, codes, and standards constraining NBS adoption can inform reviews that engage stakeholders to map implementation challenges across planning, building, infrastructure, procurement, and other frameworks. Findings from these regulatory reviews can guide updating local rules and incentives to remove prohibitive barriers and enable NBS approaches.

For example, the city of Recreio, Rio de Janeiro conducted a comprehensive review of its zoning codes and land use regulations to identify barriers to green infrastructure adoption. The assessment engaged permitting officials, developers, landscape architects, and other stakeholders to map specific code obstacles, such as restrictions on curb cuts for bioswales or limitations on roof vegetation coverage. Based on these findings, Portland updated its zoning codes to remove barriers, including increasing allowable percentages of site landscaping from 15% to 30% to accommodate more green infrastructure. The regulatory review and code update enabled greater integration of green infrastructure into new developments (Recreio green corridor, 2016).

In addition, building on the regulatory reviews, municipalities and higher levels of government can also develop supportive policies and technical standards to further incentivize NBS. New policies could mandate NBS consideration in public projects, provide bonuses for voluntary inclusion in private developments, and incorporate NBS into design standards. Adapting procurement to consider long-term benefits can also facilitate NBS adoption. Setting clear, NBS-favorable policies provide certainty while catalyzing innovation.

This strategy was particularly helpful in the Vitoria-Gasteiz, Spain case study. The city adopted new policies and standards to incentivize nature-based solutions following a review of regulatory gaps. The city mandated consideration of green infrastructure in all new public construction projects. They provided fast-tracked permitting and tax rebates for voluntary inclusion of green roofs, rain gardens, and other NBS in private sector developments. The city also updated its stormwater management manual to incorporate technical guidance on bioswale design, permeable paving specifications, and minimum NBS requirements (Implementation of the Vitoria-Gasteiz Green Urban Infrastructure Strategy, 2013)

- Leadership

Building leadership and support across public and private sectors is critical to enabling widespread NBS adoption. Identifying and empowering government decision-makers who can advocate for NBS within agencies can drive institutional change through allocated funding, supportive policies and cultural shifts. In addition, recognizing private sector developers, engineers, architects, and others pioneering quality NBS projects inspires broader industry change by demonstrating demand, showing excellence and encouraging others. Furthermore, vocal endorsements from high-level elected officials like mayors and presidents raise the profile of NBS priorities, signaling urgency and government-wide commitment.

In fact, the city of Florida created an Interagency Working Group made up of department heads from transportation, planning, water, parks, and other key agencies to coordinate and advocate for green infrastructure. This helped institutionalize NBS support and secure funding allocations. The city also recognized private architects designing innovative green buildings with its “ASLA Florida Design Awards Program”. And the mayor vocally endorsed green infrastructure, speaking at conferences and requiring consideration of NBS options for all public projects (River Landing Miami, 2022).

- Networks and communities of practice

Creating inclusive networks and communities of practice facilitates connection, learning, and collaboration across silos, which can help mainstream NBS. Knowledge sharing networks that convene diverse practitioners from government, private firms, NGOs, academia, and community groups build relationships and trust (River Landing Miami, 2022). These foster productive peer exchange and joint problem solving through working groups, conferences, and online platforms. Complementing networks, establishing jurisdiction-wide communities of practice enables coordination on NBS across multiple agencies and departments (River Landing Miami, 2022). They provide vital forums to collaboratively address barriers, plan joint initiatives, and embed systems thinking.

4.3.2 Knowledge & Capacity Building

- Developing technical capabilities

Providing training and building educational pathways to develop needed skills and expertise is key to enabling effective NBS implementation. Tailored training programs and workshops for local authorities, developers, communities and other stakeholders focused on design, delivery and maintenance of projects can build critical competencies and know-how. Hands-on elements and certifications help maximize retention and signal capabilities. Additionally, integrating NBS concepts and practices into university and college curricula for relevant fields like planning, engineering and landscaping exposes future practitioners. This mainstreaming helps build a pipeline of professionals well-versed in NBS approaches and able to successfully carry out projects.

"Training programs and integration of NBS into higher education curricula build vital expertise to enable effective design, delivery and maintenance of nature-based solutions. This capacity building helps overcome implementation barriers."

(Quito - Urban Agriculture as Nature Based Solution for facing Climate Change and Food Sovereignty, 2013, p.19)

- Generating and sharing evidence

Comprehensively documenting and widely sharing best practices, lessons learned, case studies, and how-to guidance can enable collective learning and accelerate advancement of NBS approaches. User-friendly publications, online databases, conferences, and virtual forums that compile and disseminate detailed practical knowledge on successful NBS implementation empowers further replication and continuous improvement by tapping into the experiences of early adopters. By making insights accessible, cities can foster collective learning to rapidly improve NBS deployment.

"Knowledge sharing and collective learning is imperative for advancing nature-based solutions, an emerging field where best practices are still developing. Cities should ensure documented experiences - both successful and unsuccessful - are accessible to practitioners through case study libraries, online forums, communities of practice, and other means. This enables iteration based on applied knowledge."

(Nesshöver et al., 2017)

- Building collaborative knowledge

Developing simplified decision support tools and leveraging knowledge brokers facilitates evidence-based choices and cross-disciplinary learning to enable NBS adoption. User-friendly modeling tools, visualizations, and standards help decision-makers analyze costs, benefits, tradeoffs and return on investment of NBS compared to traditional infrastructure. This builds compelling evidence and simplifies comparison. Designating professionals as "knowledge brokers" to translate technical information across sectors fosters collaborative learning. By making complex information accessible and facilitating cross-disciplinary knowledge sharing, these strategies help institutions and stakeholders make sound, evidence-based decisions to adopt NBS approaches.

In fact, Singapore created the Active, Beautiful, Clean Waters design guidelines and cost-benefit analysis models to showcase nature-based solutions for stormwater management. These resources simplified decision-making for adopting NBS options. The city also designated "ABC Waters Agents" as knowledge brokers to engage diverse stakeholders like engineers, urban planners, and landscape architects to integrate blue-green infrastructure (Bishan-Ang Mo Kio Park & Kallang River Restoration, 2012).

- Awareness raising and communication.

Launching comprehensive public awareness campaigns and organizing technical conferences enables critical knowledge sharing that can catalyze adoption of nature-based solutions (NBS). Public campaigns through media and events build understanding and appreciation of NBS benefits like recreation, quality of life, community improvement and climate resilience. This creates a more enabling environment for mainstreaming NBS approaches. Technical conferences connect researchers, practitioners, end-users, and decision-makers to share the latest scientific advances, on-ground lessons, innovations and case studies. They accelerate technical learning while fostering relationships between diverse players working on NBS.

For example, the city of Medellín, Colombia held the Green Infrastructure Conference bringing together officials, designers, engineers, and scientists to share NBS technical knowledge and case studies. Medellín also launched the "Natural Infrastructure for Life" campaign with school programs and public murals showcasing NBS benefits. These initiatives enabled crucial learning and built public appreciation to drive Medellín's green infrastructure goals (Medellín Manifesto: Learning Cities for Inclusion, 2018).

- Monitoring, evaluation and feedback

Developing comprehensive indicator frameworks and metrics enables vital long-term monitoring to evaluate NBS performance and outcomes related to wellbeing, resilience, equity and sustainability goals. Moving beyond output measures to higher outcome indicators tied to overarching objectives allows robust data collection. This provides the monitoring needed to assess effectiveness and continuously improve approaches.

Additionally, incorporating mandatory project evaluation and reporting requirements into NBS funding programs and partnerships ensures lessons are captured systematically. Evaluation criteria covering costs, benefits, risks, feasibility, user adoption and more, build collective knowledge on how to successfully scale up NBS. Synthesizing insights across project evaluations is key to building understanding of what works.

The city of Bristol developed a Natural Capital Indicators framework to track the performance of nature-based solutions across factors like air quality, recreation, and flood risk mitigation. Brisol also requires all publicly-funded NBS pilots to complete evaluation reports assessing costs, co-benefits delivered, and user adoption based on UK Green Taxonomy metrics. Insights from these comprehensive indicators and project evaluations inform decisions on implementing and scaling up the most effective NBS across the city.

- Experimentation and trials

Piloting small-scale test projects enables comparison of different NBS configurations to identify optimal localized solutions based on real-world performance data. Rapid prototyping through mockups allows quick, low-cost iteration to refine designs based on performance and public reaction before full implementation. Building on these experiments, phased installation in multiple geographic areas or increased densities gradually scales up NBS while incorporating lessons between phases. Insights uncovered in early stages inform refinements prior to going bigger. This adaptive approach reduces risks of major investments in untested solutions. Combined, piloting, prototyping and phased rollouts facilitate methodical testing, incremental refinements, and data-driven scaling of NBS. The experimental process leads to selection and improvement of optimal solutions while accumulating vital evidence to overcome uncertainties.

This strategy was adopted by the City of Singapore. The city piloted different configurations of bioswales and rain gardens to compare stormwater filtration performance. They quickly prototyped public park redesigns with movable furniture and materials to gather citizen input on preferred NBS integration before final construction. Following small-scale testing, Singapore conducted phased installation of green roofs, gradually increasing the density and biodiversity of roof gardens based on learnings about plant growth, irrigation needs, and maintenance costs from earlier phases. This iterative approach allowed evidence-based selection and continual refinement of NBS for local conditions (Bishan-Ang Mo Kio Park & Kallang River Restoration, 2012).

4.3.3 Financial & Economic

- Accessing funding

First connecting NBS practitioners to existing government grant programs in areas like environmental conservation, infrastructure development, climate adaptation, and community enhancement may provide vital capital for initial NBS pilots and demonstrations (Embleton Road SuDS, Bristol, 2019). While many current programs are underutilized, they present funding opportunities if effectively accessed. Securing public funds is crucial for establishing proof-of-concept or pilot projects to validate benefits.

Second, bundling NBS projects into financial vehicles such as green bonds, environmental impact funds, and sustainable infrastructure funds can attract substantial private capital from institutional investors seeking both financial returns and climate-aligned investments (The refurbishment of Gomeznarro park in Madrid, 2021). For instance, green bonds issued by cities like Gothenburg and Cape Town have financed expansion of green spaces, wetlands restoration, and similar NBS (CityTree, Gothenburg, 2016, Green bond for infrastructure financing in Cape Town, South Africa, 2021). Tapping global private finance reduces over-reliance on limited public budgets. Providing robust evidence regarding cost savings, revenue generation, and co-benefits is key to structuring NBS investments appropriately to draw private funding (CityTree, Gothenburg, 2016).

- Developing revenue models

Monetizing the ecosystem services provided by nature-based solutions and incentivizing decentrelized adoption on private properties can enhance financial feasibility and support mainstreaming.

Quantifying and assigning monetary values to benefits like flood control, heat mitigation, and recreation enables direct revenue streams through mechanisms such as payments for ecosystem services (PES) programs, biodiversity offsets, stormwater credits and green bonds (City of Philadelphia, 2022). For instance, Philadelphia Water's stormwater credit trading system has monetized NBS flood mitigation benefits, funding scaled green infrastructure implementation. Stacking multiple revenue streams from NBS further enhances income potential. Additionally, valuing services in financial terms moves beyond “abstract appreciation” to provide sustainable funding tied to NBS performance and benefits delivery (Ojea, 2015).

As explained in City of Philadelphia (2022), *"Monetization of the stack of services provided by NBS has the power to capture values that shift investments towards NBS and away from traditional grey infrastructure"* (p. 11).

Furthermore, incentives for private landowners—like grants, tax breaks, technical assistance, and recognition—have proven effective for motivating adoption of NBS on distributed individual properties from home gardens to industrial sites (Wendling et al., 2018). For example, Philadelphia’s Stormwater Management Incentives Program saw rapid green infrastructure expansion on private parcels following launch of fee discounts and grants (City of Philadelphia, 2022). Incentives share costs and align NBS with financial motivations of landowners.

- Sustained funding

Establishing long-term, reliable local funding sources for NBS through recurring allocations of taxes, fees, or other public revenue streams provides sustained investment and reduces dependence on one-time project grants. For instance, the city of Vitoria-Gasteiz, Spain implements a municipal budget funded via solid waste fees that provides consistent investment in green infrastructure. Creating dependable funding alignments like shares of property taxes or developer impact fees can enable stable NBS financing on the model of transit, housing, and parks funds commonly used in cities (Vitoria-Gasteiz: Nature-based Solutions (NBS) Enhancing Resilience to Climate Change, 2019).

Additionally, conducting detailed cost-benefit analyses and economic assessments quantifying “total lifetime costs” versus “complete value streams” - including enhanced ecosystem services, health benefits, jobs created, increased property values and tax revenue - builds compelling business cases for NBS with strong financial justification. For example, cost-benefit analysis of the Klang River basin restoration in Malaysia demonstrated a positive return ratio, catalyzing implementation (Klang River Ecological Restoration, 2018). Rigorously monetizing services provokes buy-in from fiscal decision makers otherwise skeptical of NBS investments Klang River Ecological Restoration, 2018).

- Innovative & financing mechanisms

Developing investment prospectuses tailored for dual-objective impact investors attracts financing for NBS, given their sustainability merits. For instance, the NBS prospectus for Washington D.C.'s Green Bonds engaged impact investors, raising $15 million (Hsu et al., 2017). Professional advisors can further facilitate structuring investable NBS deals and conducing investor roadshows, as the Montgomery County Green Bank demonstrated (Carey et al., 2022). This connects NBS implementers to aligned impact capital seeking both financial returns and social/environmental value.

In addition, instruments like loan guarantees, green bonds, revolving loan funds, and microloans provide affordable, longer-term debt financing for NBS without diluting ownership, as Toronto and Cape Town have exhibited (Hsu et al., 2017). Many community development financial institutions offer tailored NBS debt products, like the Prospect Park Alliance's financing for Brooklyn green space (Arup, 2016). Loan guarantees and pooled small-scale projects allow access to larger bond issuances, as the DC Water Environmental Impact Bond demonstrated (DC Water, 2022). Aligned debt enables funding while retaining oversight.

Moreover, civic crowdfunding platforms match grassroots NBS demand with small donations, as platforms like Citizinvestor have shown (Citizinvestor, 2022). For example, Buffalo Bayou Partnership's crowdfunding engaged residents in revitalizing Houston's waterfront (Houston Parks Board, 2022). Geotargeted campaigns and creative rewards build community buy-in for neighborhood NBS.

- Partnership models

Public-private partnerships (P3s) can overcome implementation and financing barriers by leveraging private sector expertise and investment for delivering major nature-based solutions. As demonstrated in the Atlanta BeltLine project, "…*the P3 structure allowed over $500 million in private financing while ensuring green space, trail* *connectivity, and affordable housing requirements were contractually met*." (Suburban Land Reserve, 2021). By tapping specialized capacity and access to significant capital, while transferring risks away from resource-constrained public agencies, P3s allow for relying on critical private sector capacity and funding to advance complex NBS initiatives. Defining key performance indicators and asset "handback" conditions further maintains public control over sustainability outcomes. When thoughtfully structured, private involvement can thus help overcome chronic barriers to implementing ambitious nature-based solutions.

Moreover, partnering with corporations can support sponsored NBS projects as part of their Corporate social responsibility (CSR), Environmental, Social and Governance (ESG) plans and sustainability programs. Corporations may fund restoration, green space access or climate resilience projects that align with their values and business objectives (e.g. around nature, equity, climate). In fact, the German company CleanGreen partnered with Forests for All to sponsor urban tree planting in Berlin and Munich. CleanGreen provided €75,000 in funding to support Forests for All's programs to plant trees and expand green spaces in inner-city areas. This partnership aligned with CleanGreen's sustainability values around offsetting carbon emission (Climate-Smart Forestry Case Study: Germany, 2022). Therefore, such partnerships provide new financing streams.

4.3.4 Collaboration & Engagement

- Community-focused outreach

Strategically highlighting quality of life benefits like recreation access, public health, social cohesion, and community revitalization can make NBS initiatives locally valued and relevant. As explained in the city of Bristol case study, *"Promoting the cooling effects and increased access to green space provided by urban tree planting garnered broad public support for expanding tree cover"* (Elderberry Walk, 2022, p.14). Local co-benefits resonate widely across demographics. By clearly communicating NBS advantages for enhancing recreational amenities, improving neighborhoods, and revitalizing communities, cities can build a persuasive case for NBS based on improving daily life for all residents. This compelling narrative around experiential local benefits transcends political, cultural and socioeconomic divides, fostering broader advocacy.

- Co-design and collaboration

Undertaking inclusive community outreach enables collaborative co-design processes where residents actively shape local nature-based solutions. As demonstrated through New York's Staten Island Blue-belt wetlands expansion, *"Holding public meetings, workshops, and school programs fostered co-creation, with community priorities integrated into the design."* (DEP, 2022, p.11). Co-design venues should reduce participation barriers. Hands-on engagement builds buy-in, ownership, and tailors NBS to community context. As Hamburg's Cloudburst Management Plan found, "Site visits and design charrettes empowered bottom-up planning of green stormwater infrastructure." (ReBuild by Design, 2020). When communities co-create solutions, NBS becomes more relevant, equitable, and uniquely responsive to local needs.

- Hands-on involvement

Creating accessible volunteer opportunities deepens personal connections with nature and fosters community investment in local NBS, as Rotterdam experienced: *"Organizing inclusive tree planting days brought together all ages and backgrounds to participate."* (Rotterdam Climate Initiative, 2021, p.16). Citizen science initiatives likewise engage communities while providing data to improve NBS, as seen in Helsinki's "Urban Nature Watch" program enlisting residents in biodiversity monitoring (City of Helsinki, 2022, p.28). As they found, *"Opening indicator data transparency increased awareness of NBS benefits."* When people actively participate through stewardship and science, it cultivates collective understanding and attachment to NBS success.

- Communications and media

Celebrating early NBS successes publicly builds enthusiasm and momentum for further implementation and scaling, as Philadelphia demonstrated when *"media coverage of initial bioswale performance generated city-wide excitement for green stormwater infrastructure"* (Philadelphia Water Department, 2021, p.41). Diverse communications channels ensure broad visibility. Recognizing project leaders through awards and appreciation events further motivates expanded leadership on NBS advancement, as exemplified by Singapore's "Skyrise Greenery Awards" honoring green building contributions (National Parks Board, 2022). Early milestones should be mentioned to attract wider adoption. By broadcasting achievements and honoring pioneers, cities can accelerate the mainstreaming and implementation process.

- Digital engagement

Targeted social media campaigns can creatively engage diverse audiences on nature-based solutions, as Paris demonstrated through their “Greening My Hood” youth contest showcasing local green spaces (Paris Environment Dept, 2022). Timely, visual content raises awareness. Complementing viral campaigns, digital community hubs like Toronto’s Green Infrastructure Portal provide interactive public access for NBS education, project mapping, planning updates, feedback, volunteering and events (City of Toronto, 2022). Integrated social media expands reach, while digital forums increase transparency and dialogue around NBS initiatives. By meeting and educating the audiences, cities can increase understanding, participation, and informed advocates for expanding NBS.

CHAPTER 5
DISCUSSION

The analysis found that barriers in terms of knowledge, policies, financing constraints, and collaboration hindered NBS implementation. These barriers manifest frequently across cities globally. However, promising solutions are emerging. Entities advancing NBS have utilized multifaceted strategies to overcome barriers, from building collaborative governance structures to reforming restrictive policies. Strategic approaches can pave the way for NBS to realize their potential in enhancing urban climate change adaptation. The study also delineated the frequency of barriers across contexts worldwide, addressing a gap in existent literature. With evidence-based, locally tailored solutions, cities can create environments favorable to unlocking the full potential of nature-based solutions for equitable and sustainable climate adaptation.

5.1 Strategies to Overcome Barriers to Urban NBS Implementation for CCA

This study validated that major barriers around municipal policies, knowledge gaps, stakeholder collaboration, and financing continue to constrain NBS uptake, echoing extensive literature (Chan et al., 2018; Frantzeskaki et al., 2014; Kabisch et al., 2016). However, a granular analysis revealed nuances.

National and Municipal policies and legislation have emerged as the most prevalent barrier to urban NBS uptake based on this global analysis. Outdated policies, codes, zoning regulations and standards at the city-level pose immense obstacles that hinder NBS integration (Hansen et al., 2017; Lennon et al., 2021). This study found such policy challenges arising in over 70% of the assessed cases worldwide, validating claims in academic literature about the barrier's widespread nature. Fundamental municipal policy reforms through legislative changes, updated standards and flexible regulations are essential for mainstreaming NBS on a broad scale (Lennon et al., 2021).

"Urban planning policy, rules, regulations and governance arrangements fundamentally shape possibilities for NBS interventions. Urban planning policies and bylaws need to be sufficiently flexible and inclusive to avoid constraining innovations like NBS...More fundamental transformations are required in policy and planning to shift from 'grey' to NBS approaches. Changes are required beyond 'tweaking' current systems."

(Green corridor in Passeig de Sant Joan, Barcelona (ENABLE project), 2021, p.26)

While innovative collaborative governance arrangements can help overcome problematic policies temporarily, these workarounds fail to resolve the root issue. They may enable standalone NBS projects but cannot mainstream adoption citywide. As Mguni et al. (2022) explained, governance-related challenges reduce the potential to transition toward NBS if the policy context is not thoroughly considered. Policy reform is fundamental, but requires substantial time, consensus-building, and political will.

Some argue that collaboration alone can drive change (Frantzeskaki et al., 2014), but evidence shows that flexible, NBS-friendly policies are a prerequisite for mainstreaming (Kabisch et al., 2016). Ad hoc collaborations provide temporary relief but leave systemic barriers intact. What is required is dedicated efforts toward reforming outdated policies, codes, zoning, and regulations that hinder NBS integration.

Municipal policies also constrain sustained funding for NBS operations and maintenance. Policy improvements that institutionalize NBS through codes, standards and regulations are needed to surmount this barrier (Hansen et al., 2017).

"... insufficient funding for long-term maintenance of the rain gardens due to lack of established policies or requirements. Maintenance was addressed ad-hoc. Updated municipal policies and standards requiring consideration of maintenance costs upfront in project approval and providing dedicated funding streams would sustain NBS investments already made."

(EEA grants supporting the city of Bratislava to implement climate adaptation measures, 2017, p.19)

Overcoming systemic policy barriers is thus crucial to unlocking the potential of NBS. This will require substantial time, consensus-building, leadership and political capital. But with strategic policy reforms, cities can pave the way for mainstreaming NBS and realizing their immense potential for advancing climate adaptation, sustainability, and community wellbeing.

While municipal policy barriers proved most frequent, the criticality and urgency of dismantling different barriers matter tremendously. Knowledge gaps and collaboration difficulties can severely hinder NBS adoption. As Chan et al. (2018) found, limited knowledge and weak governance structures often reinforce each other, creating compounding barriers. Knowledge gaps lays a vital foundation for NBS success. Studies show that lack of awareness on what NBS entails and how it can support policy goals constrains uptake (Mguni et al., 2022). Targeted educational initiatives are essential to build widespread understanding (Kabisch et al., 2016).

"Lack of understanding of NBS benefits among officials and citizens was a major barrier… Broad educational campaigns helped increase knowledge and appreciation of NBS, which is vital for mainstreaming uptake."

(Four pillars to Hamburg's Green Roof Strategy: financial incentive, dialogue, regulation, and science, 2022, p.37)

Furthermore, this study identified project timeline as a critical new knowledge barrier requiring special attention. As highlighted in the results, stakeholders often face difficulties in defining appropriate timeframes for complex NBS initiatives. These nature-based solutions require careful long-term planning and monitoring that many lack expertise in (Chan et al., 2018). As the findings showed, this knowledge gap results in frequent project failures and suboptimal outcomes. In fact, climate change adaptation necessitates adaptable, long-term strategies (Lennon et al., 2021). But insufficient timeline knowledge causes cities to underestimate requirements. This emphasizes the need to balance between urgency and thorough NBS planning (Hansen et al., 2017). Addressing the project timeline knowledge gap requires thoughtful approaches that allow adequate phasing, iteration, and refinement of NBS. Therefore, building expertise in scoping NBS timelines is vital and it represents an underexplored but critical barrier requiring dedicated efforts and knowledge sharing. Strategies like project piloting, incremental scaling and flexible adaptive management are vital to overcoming rigid project timeline barriers that often undermine NBS success (Hansen et al., 2017). These adaptive strategies enable timelines to be adjusted based on evidence, preventing initial schedule limitations from leading to failure.

Likewise, collaboration barriers pose major challenges for NBS implementation. NBS requires coordinated efforts across government, communities, and the private sector

(Frantzeskaki et al., 2014). But siloed thinking makes integration difficult (Mguni et al., 2022). Strategies like establishing multi-stakeholder partnerships, cross-sectoral coordination departments, and communities of practice can help overcome this barrier. In fact, the creation of centralized coordination units focused on NBS facilitates streamlined processes and alignment across government agencies, as demonstrated in Toledo, Ohio's Green Infrastructure Maintenance Program (2022). Additionally, forming multi-stakeholder partnerships across government, community, private sector, and academia allows synergies to emerge from shared resources, costs, expertise and vision aligned under NBS goals, as elaborated in the Beira, Mozambique case (2020). Furthermore, as explained through the Miami, Florida case (2022), communities of practice involving diverse practitioners enable vital information exchange and relationship building to mainstream NBS approaches within and across institutions.

In addition, financial barriers pose major challenges to NBS adoption. In fact, urban infrastructure is usually regarded as a field tackled by the government, thus there is a lack of public investment for sustainable urban infrastructure. Therefore, municipal spending restrictions coupled with profit-motivated private developers have produced underinvestment in NBS (Kabisch et al., 2016). However, attitudes are shifting. Public engagement is increasingly recognized as crucial for NBS success (Lennon et al., 2021). Governments are thus partnering with private entities to fund NBS through innovative models (Hansen et al., 2017). Strategies like public-private partnerships, cost-benefit analysis, and various finance instruments can help overcome financial barriers by leveraging specialized private expertise and capital (Shanahan et al., 2021). As exemplified in Atlanta's River Waal project, partnerships enabled private investment for green space connectivity (Room for the River Waal – protecting the city of Nijmegen, 2015). Accessing grants, bonds, and impact funds creates a pool of resources across sectors to overcome NBS financial barriers (Kabisch et al., 2016). Engaging community and corporate financing options further distributes costs and ownership, while increasing buy-in (Hansen et al., 2017). Additionally, monetizing the wide-ranging ecosystem services provided by NBS unlocks viable revenue streams closely aligned with the benefits NBS deliver.

On another note, perceptions around certain barriers are evolving in positive ways. Lack of private sector interest was encountered in only 6% of the case studies, which is very minimal compared to the other barriers, contradicting some claims in the literature. In fact, active participation and buy-in from companies was observed in many cases, reflecting an evolution in market preferences (Lennon et al., 2021). Actually, substantial funding is now flowing from private corporates and financial institutions to support NBS initiatives, especially in Europe and North America (Papari et al., 2024). This shift aligns with emerging mandatory sustainability disclosure regulations that compel consideration of environmental, social and governance (ESG) factors in business and investing (Shanahan et al., 2021). Frameworks like the EU's Sustainable Finance Disclosure Regulation (SFDR), CDP reporting standards, and the IFRS Sustainability Standards Board (ISSB) are mobilizing demand for sustainable assets and catalyzing NBS investment (Papari et al., 2024). By requiring climate risk exposure transparency alongside demonstrations of resilience plans, these reporting frameworks incentivize private sector support for NBS as a mechanism for enhancing adaptation efforts.

However, some challenges persist around accurate quantification of emissions reductions and resilience impacts from NBS investments. Market claims have outpaced verified measurement frameworks, undermining reliability (Papari et al., 2024).

Developing standardized metrics and verification systems is thus necessary to optimize private financing (Papari et al., 2024). Overall, disclosure regulations are transforming investor and corporate mentalities to unlock substantial financing for NBS through a symbiotic motivation structure of regulatory compliance driving voluntary sustainability prioritization.

Furthermore, driven by this market demand and branding benefits, companies increasingly view NBS as advantageous (Shanahan et al., 2021). This reveals a promising transition beyond static views of private sector reluctance. In addition, as societal awareness and business cases expand, barriers transform into opportunities. Similarly, lack of investments and demand for NBS did not emerge as major barriers. Stakeholders made purposeful decisions to undertake NBS initiatives through organizational targets and goals (Frantzeskaki et al., 2014). This further counters notions of lack of interest and financing limits as major barriers.

In addition, shortages of skilled labor also failed to prevail as a major barrier as highlighted in section 4.2. This is due to the idea that entities proactively build capacity through training programs and knowledge sharing (Mguni et al., 2022). However, it is important to note that business motives may not automatically serve public goals (Shanahan et al., 2021). Strategic partnerships and incentives are still needed to optimize private sector roles and financing mechanisms. In fact, recent advancements are actively alleviating capacity challenges that have historically hindered NBS execution. This promising evolution links several key progress areas.

Firstly, the proliferation of user-friendly digital design and monitoring tools now enables practitioners to model and optimize NBS initiatives with limited technical backgrounds (Linnerooth-Bayer, 2023). Platforms like DREAM-DESIGNER dramatically simplify modeling of green infrastructure combinations for urban renewal contexts across disciplines (Jiang et al., 2021). These technologies provide intuitive visual interfaces and extensive visualization features for scenario building, empowering novice teams with limited NBS exposure to develop innovative nature-based solutions (Linnerooth-Bayer, 2023).

Additionally, extensive global knowledge exchange networks focused explicitly on gathering and disseminating NBS resources are filling experience gaps. The Nature4Cities project alone has compiled over 1000 NBS case studies for practitioners to learn implementation best practices (Nature4Cities, 2023). Multiple global communities of practice like the IUCN Urban Alliance and C40 Cities likewise connect practitioners to share lessons around NBS barriers and enablers. These networks proliferate specialized insights across contexts that local organizations previously struggled to develop independently.

Moreover, funded NBS research initiatives and demonstration projects are producing extensive technical guidelines and codified knowledge outputs tailored for widespread replication. In Europe, the Horizon2020 PHUSICOS program has yielded over 50 readily adaptable tools and methods documents to upgrade competencies around NBS planning, governance and impact evaluation (Linnerooth-Bayer, 2023). Meanwhile demonstration initiatives like the Connecting Nature project are validating NBS efficacy across habitats to build investor confidence and community buy-in while lowering execution risks for following projects (Connecting Nature, 2022).

Therefore, due to the mainstreaming of user-friendly modeling instruments, growth of collaborative NBS knowledge ecosystems, and investments in institutionalizing NBS expertise across sectors, the barrier of limited organizational capacities no longer stands as the insurmountable impediment previously presumed Hence, perceived barriers can evolve in positive ways over time. But a nuanced understanding is required to create these opportunities.

This research also revealed insights into how strategies are deployed across stakeholder groups. Private actors favored financing innovations and contractual tools aligning with business motives (Hansen et al., 2017). Public entities prioritized policy reforms targeting governance mandates (Mguni et al., 2022). Communities utilized collaboration and engagement strategies reflecting local interests (Frantzeskaki et al., 2014). However, additional research in this area is required to further define the relationship of which actors mainly used which strategies. This can facilitate the implementation process by allowing a sound distribution of strategies across stakeholders.

Furthermore, it is clear based on this research that certain strategies address multiple barriers synergistically. Therefore, enabling widespread adoption of NBS for enhanced climate adaptation in cities requires overcoming persistent multilevel barriers. For instance, collaborative knowledge building across sectors provides benefits beyond just capacity, also enabling policy and collaboration barriers to be overcome (Hawxwell et al., 2019).

Strategies like multi-stakeholder partnerships and communities of practice convene diverse expertise while fostering vital relationships and information flows across silos (Neufeldt et al., 2020). This enhances knowledge and capacities while overcoming barriers between agencies, sectors and disciplines.

Additionally, regulatory reviews engaging diverse stakeholders inform policies while increasing buy-in and understanding between groups (Zuniga-Teran et al., 2019). The collaborative process creates innovative insights and builds connections. For instance, Mexico City enacted regulations requiring green roofs and rainwater harvesting while also launching awareness campaigns and financial incentives for private owners (Shanahan et al., 2021). The blend of requirements, outreach and financing spurred NBS integration.

Similarly, participatory planning enables contextual policies while fostering dialogue and trust between communities and officials (Dorst et al., 2022). Citizens gain knowledge while officials learn from on-ground realities.

The chart below presents the relationship between the barriers and corresponding strategies.

Table 12. Relationship between barriers and strategies - Case Studies

	Barriers	Strategies
Policy	Municipal Policies	• Develop supportive policies. • Form partnerships across sectors. • Enable participatory governance. • Improve coordination. • Incentivize sustainability. • Demonstrate leadership.

	National Policies	• Develop supportive policies. • Form partnerships across sectors. • Demonstrate leadership.
Knowledge	Skilled labor and Organizational Capacities.	• Develop technical capabilities. • Build collaborative knowledge.
	Performance and Evidence	• Generate and share evidence. • Build collaborative knowledge. • Monitor, evaluate and provide feedback.
	Project timeline	• Experiment and trial approaches. • Monitor, evaluate and provide feedback. • Enable participatory governance. • Improve coordination. • Demonstrate leadership. • Build knowledge-sharing networks.
	NBS field development	• Develop technical capabilities. • Generate and share evidence. • Build collaborative knowledge. • Experiment and trial approaches
	Demand and investment	• Develop sustainable revenue models. • Develop innovative financing mechanisms.

Financial		• Develop public-private partnership models.
	Maintain cost and monitoring	• Ensure sustained funding across cycles. • Monitor, evaluate and provide feedback.
	Cost-benefit analysis	• Access various sources of funding. • Ensure sustained funding across cycles. • Develop innovative financing mechanisms.
Collaboration and Engagement	Private sector support and engagement	• Incentivize sustainability. • Demonstrate leadership. • Develop public-private partnership models.
	Public acceptance and engagement	• Community focused outreach • Co-design and collaboration • Hands-on involvement • Communication & Media • Digital Engagement
	Lack of collaborative governance systems	• Form partnerships across sectors. • Enable participatory governance. • Improve coordination. • Demonstrate leadership. • Build knowledge-sharing networks.

Therefore, cities globally are making progress through targeted, multifaceted strategies tailored to overcoming implementation barriers. Employing a mix of regulatory, social and financial instruments jointly is an effective approach for enabling NBS implementation.

Strategic policy reforms, legal frameworks and updated standards help address regulations and policies that severely hindered NBS implementation (Hansen et al., 2017). Participatory governance further adapts inflexible legislations to community priorities (Dorst et al., 2022). Central coordination units connect siloed agencies, allowing integrated NBS deployment (Lennon et al., 2021).

Financing represents another barrier, but instruments like bonds, public-private partnerships and revenue models have unlocked funding streams aligned with NBS benefits (Kabisch et al., 2016). Impact investors and corporate sponsors additionally distribute costs and risks amidst municipal/national budget constraints. Innovative financing thus sustains investments that deliver ecological returns.

Knowledge and capacity building similarly help overcome barriers around awareness, technical skills and NBS evidence (Mguni et al., 2022). Documentation, training programs and project piloting make NBS implementation more achievable.

Likewise, community-centric engagement through co-design, volunteering and stewardship fosters public buy-in and tailored local solutions where lack of acceptance posed challenges (Frantzeskaki et al., 2014).

Project timelines represent a nuanced challenge, but phased piloting enables reasonable flexibility to balance urgency with methodical planning (Shanahan et al., 2021). In addition, experimentation prevents tight schedules from undermining social and environmental challenges.

Applying these strategies together produces an enhanced collective impact beyond what individual strategies yield in isolation. Policy reforms enable financing, engagement drives political will, knowledge underpins social acceptance (Hansen et al., 2022). As complex interacting systems, cities require integrated approaches targeting leverage points across barriers simultaneously (Sussams et al., 2015).

Therefore, tailored policy mixes, innovative financing, capacity building and community inclusion together transform environments to nurture multifunctional NBS success. The pathways are context-specific but the principles universal. With deliberate, patient, systems-aware efforts, cities worldwide can overcome barriers to mainstream NBS for collective climate adaptation.

5.2 Recommendations for NBS Implementation

Based on this research some recommendations for NBS uptake are proposed. These recommendations consider the identified barriers and related strategies that facilitate NBS implementation in an urban context for CCA.

Four big ideas are proposed that minimize the risk of failure as much as possible and should be applied during the early stages of NBS planning in order to have a comprehensive prediction of possible barriers and enablers that can be adopted accordingly.

5.2.1 Clear vision of NBS project against climate change impacts

It is important to have a clear vision for the NBS project. This can be achieved by understanding the context specific climate change challenges, their expected impacts, and the goal to be achieved. The vision should address all the pillars of NBS including environmental, economic and social challenges without prioritizing any of the three aspects (Hansen et al., 2022). In fact, in 87% of the case studies, planning of NBS was done through consultation with several stakeholders i.e., citizens, academia, skilled labor and municipality in order to develop a shared vision addressing not only environmental or ecological challenges, but also societal impacts and financial concerns. This is particularly important as various resources are different across cities, thus prioritizing all predicted challenges is important.

Climate change challenges can be identified and prioritized mainly through consultation and participation with all concerned stakeholders, most importantly citizens directly affected by the impact of CC (Dorst et al., 2022). It is important to emphasize that consultation is not strictly related to affected citizens rather it should include all stakeholders. This will provide an enhanced idea regarding possible CC challenges and enrich the vision of the project allowing for a stronger development and implementation of the NBS initiative.

However, as stated in the case studies, consultation with multiple stakeholders to prioritize challenges might be difficult, particularly when macro-level and micro-level stakeholders are consulted (Donnell et al., 2017). This is due to the idea that macro-level stakeholders might provide a more strategic point of view while micro-level actors might adopt a more limited vision related to the geographical scope of the project. However, even if the process might be lengthy, it is of utmost priority as it reflects on all possible aspects related to the project (Donnell et al., 2017). Nonetheless, and as reflected in the strategies section, this procedure can be less challenging through liaison actors. Such actors coordinate across all the groups and facilitate the development of a shared understanding among them.

5.2.2 Development of potential NBS solutions

After the prediction of climatic challenges, cities should reach their vision in terms of which NBS project(s) to implement. This will be done by recognizing all possible NBS solutions that are related to the previously identified potential challenges. Based on this research, consultation with multiple stakeholders is important. These actors can identify the needed NBS intervention based on the documented performance and impacts of previous NBS initiative across environmental conditions (Kabisch et al., 2016). It is important to keep in mind that the choice of NBS is mainly dependent on the potential location(s) of the project and knowing where a possible initiative will be initiated can help reduce the number of potential NBS projects (Kabisch et al., 2016). Based on the literature, multiple guides for identification of ideal sites for green initiatives exist, such as the green infrastructure planning methods (Meerow et al., 2017; Kremer et al., 2016; Norton et al., 2015). In addition, possible NBS projects should be assessed against various other indicators, including community development impact, financial viability, policy alignment and implementation feasibility (Meerow et al., 2017). These indicators will influence the choice of the NBS project. Several tools can be used to carry out this assessment such as spatial optimization models and multi-criteria decision matrices (Meerow et al., 2017).

An important concern might arise in this situation, where knowledge gaps and lack of data related to impact and performance of NBS projects exist. Therefore, having clearly documented data related to performance of NBS projects is important, however, when data lack, pilot projects at small scales are beneficial. They can help understand the various aspects of the initiative before deploying the final project (Kremer et al., 2016).

Here comes the need for multiple stakeholder consultations. Micro-level players can enhance this stage with their local grassroots understanding of shorter-term needs and preferences, while macro-level actors can enhance the process with their larger perspective on the longer-term and large-scale benefits deriving from NBS (Donnell et al., 2017).

5.2.3 Identify current and predict possible barriers.

Every city will face its own set of challenges hindering NBS project implementation; therefore, potential barriers should be assessed across policy, financial, knowledge and collaboration dimensions. In addition, including multiple stakeholders at all stages of the planning and implementation processes can help identify a comprehensive list of barriers across all aspects of NBS (Van der Jagt et al., 2021). Macro-level actors are more likely to be acquainted with potential political and institutional barriers, whereas micro-level actors might be more familiar with project-specific barriers (Mguni et al., 2022). Transboundary or liaison individuals can aid by discovering the links and interactions between various barriers. Based on the literature methods such as interpretative structural modeling (or ISM) has been used to model barriers and identify their interconnections in complicated circumstances (Winz et al., 2013). Additionally, benchmarking failures and success experiences from different cities can aid in identifying and forecasting possible barriers. This step is particularly important because the process of identifying barriers may result in revisions to the initial vision and/or preferences for certain solutions (Kabisch et al., 2016). Furthermore, by broadening the assessment on challenges beyond purely environmental dimension, cities uncover various barriers that can largely affect the successful implementation of the NBS project (Sussams et al., 2015).

5.2.4 Identify current and predict possible strategies.

For the implementation of NBS, key enablers include creating partnerships between stakeholders, efficient monitoring, knowledge sharing, financial instruments, plans and legislation, education and training, open innovation and experimentation, and proper planning and design. The presence of numerous actors can enhance the identification of enablers (Van der Jagt et al., 2021). Micro-level actors are better positioned to identify project- and design-related enablers than macro-level actors, who can more easily map institutional and organizational enablers (Meerow et al., 2017). The identification of new, potential strategies, as well as the defining of the most relevant activities, depends on the collaboration between these two actors using a multidimensional perspective (Meerow et al., 2017).

At this point, iterating prior actions or steps to improve outcomes can be crucial. For instance, if an enabler is expensive or can only be implemented over a long period of time actors may prioritize challenges and solutions differently (Van der Jagt et al., 2021). The research has provided a clear picture related to how enablers may alleviate a particular barrier. In addition, it was explained that one strategy can be used to overcome multiple barriers, therefore, stakeholders should have a broad vision and try to link certain strategies to multiple barriers when applicable.

5.2.5 Develop action plans

With priority barriers diagnosed and enabling strategies mapped, cities must translate insights into action through targeted implementation plans (Hansen et al., 2022). Just as barriers interact dynamically, strategies must also be implemented in an interconnected manner targeting priority gaps while leveraging existing strengths (Frantzeskaki et al., 2019).

Plans should outline policy mixes that pair regulations, financial instruments and social interventions for holistic transformations (Dorst et al., 2022). For instance, stormwater fees providing sustained financing can be combined with policies mandating on-site incorporation of green infrastructure elements. Strategic sequencing also matters where early success through demonstration sites inspire wider buy-in enabling more ambitious policy reforms (Mguni et al., 2022).

In addition, governance and accountability mechanisms like committees and participatory monitoring linking decisions across agencies and stakeholders are vital (Kabisch et al., 2016). Embedding inclusive governance, community oversight and flexibility to refine approaches sustains outcomes over political cycles.

Therefore, cities can promote the use of NBS to improve urban climate adaptation by taking an inclusive approach to urban planning and governance. Specifically, cities should develop integrated action plans that pair complementary strategies across different domains. By ensuring involvement and collaboration among diverse stakeholders through an inclusive governance process, cities create environments fostering NBS implementation targeted towards enhancing urban climate adaptation.

CHAPTER 6
CONCLUSION

While nature-based solutions (NBS) offer tremendous potential for building climate resilience in cities, there are still barriers hindering their broader implementation. Through studying real-world cases, barriers hindering NBS implementation were identified. These include limited organizational skills to deliver NBS projects, restrictive policies and regulations, lack of financial incentives or business models, and difficulties in terms of citizens and stakeholders' engagement.

The research also highlighted that there are practical strategies that can be used to overcome these barriers. Building knowledge across departments is crucial. This can be achieved through workshops, visiting projects in other cities to learn from various experiences, and implementing small pilot studies to build expertise. In addition, it is important to work closely with policymakers to adjust outdated policies and develop new standards adapted to NBS. When it comes to financing NBS projects, subsidies, revolving loans and stressing the whole life-cycle cost savings of NBS over gray infrastructure are considered as viable options for NBS implementation. Furthermore, citizens' engagement from the start through participatory design processes is crucial because this helps avoid any unforeseen opposition and also provides insights in terms of the most urgent climate change impacts affecting the general public.

The identified strategies are applicable across scales and projects, therefore, actors or stakeholders aiming to implement NBS should proactively identify potential barriers and deploy appropriate strategies early on. This will contribute towards a higher success rate of NBS implementation in cities. It is important to keep in mind that it requires commitment from both public and private sectors to overcome barriers obstacles and enable the implementation of NBS projects.

An important takeaway from this research underscores how different barriers obstructing nature-based solutions implementation rarely happen on their own but rather tend to compound across policy, financial, community, and knowledge spheres. Because of these interconnections, responses need to also engage with all these challenges in a coordinated way. The global case evidence shows that multiple strategies are needed to target one specific challenge point unique to each place. Single narrow solutions often fail against systemic blockages. But the findings make clear that with purposeful collaboration across entities, cities can thoughtfully dismantle barriers piece by piece, even deeply rooted ones.

Additionally, the global study shows many examples of different collaborative strategies that cities used successfully to overcome typical bureaucratic delays. Even though the specific challenges and opportunities are very different across regions, the cases present several solutions that can be tailored to a specific context. When decision-makers recognize interconnected barriers and address them with coordinated solutions tailored to local situations, cities can understand how to implement needed nature-based projects.

Furthermore, the analysis shows that by building committed partnerships focused on expanding community access, many recurring governance, social and financial barriers obstructing nature-based implementation can be overcome. When cities comprehensively rethink their policies, budgets, and civic engagement processes together alongside residents, the resulting NBS project can provide stability for communities navigating climate change impacts. Essentially, by highlighting real-world cases where collaborative innovation successfully navigated challenges, this thesis strengthens confidence and practical evidence for decision-makers pursuing the major development shifts required to adapt cities to intensifying environmental uncertainty.

While the real-world case studies analyzed provide important evidence for barriers and potential strategies related to implementing nature-based solutions, more research is still needed to validate and refine the findings. The case analysis methodology allows for in-depth understanding of challenges and solutions within global contexts. However, the insights may not be applicable in certain limited specific contexts. As practitioners and policymakers around the world increasingly consider NBS adoption, systematic monitoring, and assessment of additional empirical cases over time could uncover novel barriers, surfacing place-based nuances. This would support the refinement and expansion of the strategies proposed here. In addition, long-term tracking could evaluate sustainability of solutions themselves. If certain strategies appear less effective over enduring timescales, alternatives may need to be identified. By continuing to learn from experience with rigorous case study analyses, knowledge, and best practices for enabling NBS can continuously advance.

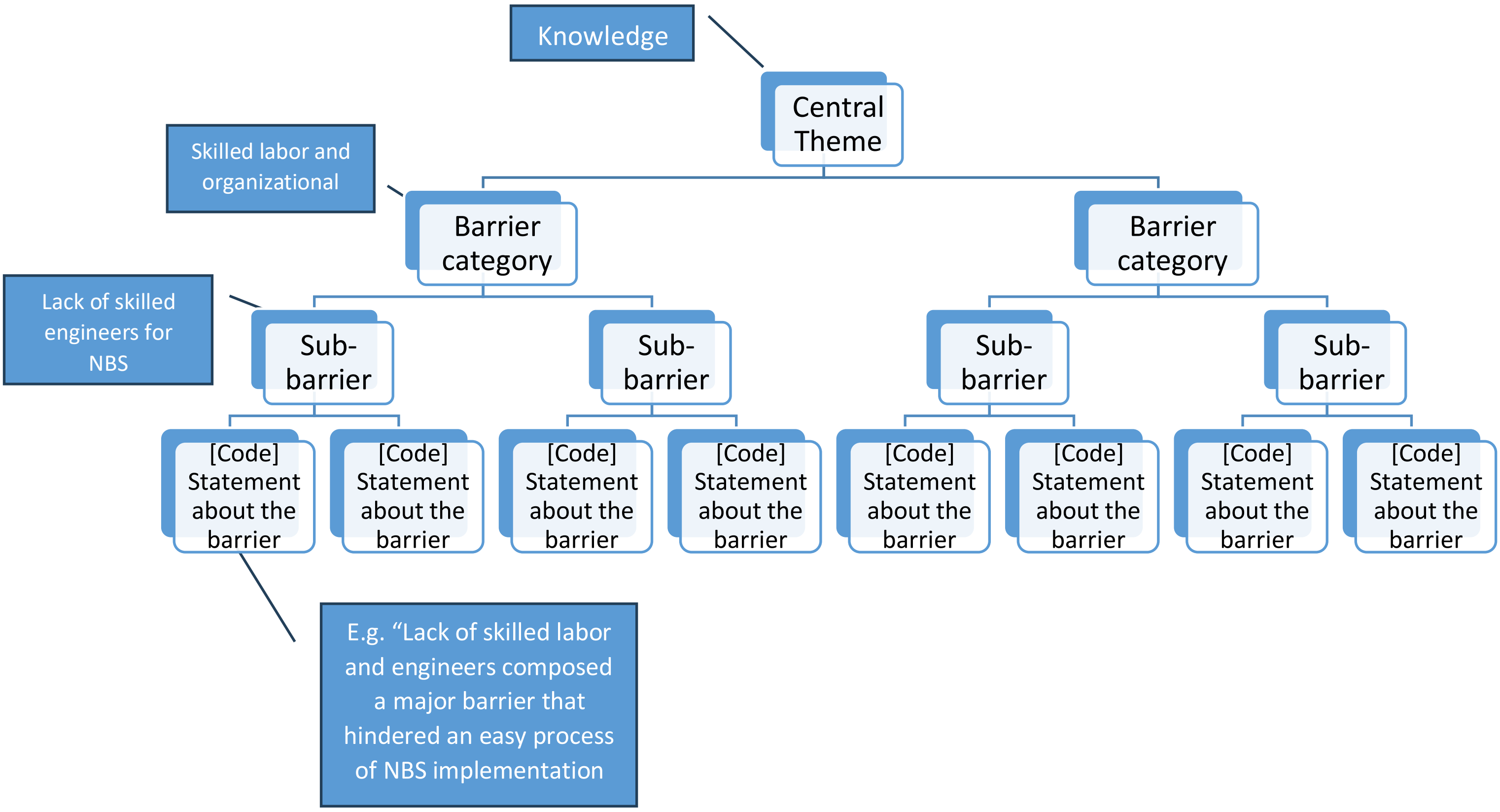
Additionally, the policy, financing, and engagement solutions proposed require high levels of cross-sectoral collaboration which can be difficult to coordinate and sustain in practice. Success likely depends on strong leadership and the ongoing commitment of both public and private stakeholders. If support wavers over time, the strategies outlined here may falter. Sustained monitoring and evaluation of NBS outcomes will be needed to demonstrate benefits and encourage continued investment.

Finally, while NBS offer tremendous potential, trade-offs with other urban planning priorities, particularly real estate, could emerge and require careful navigation. Planners must find balanced approaches that address multiple city goals around transit, housing, jobs, recreation etc. in addition to climate resilience and sustainability. If scaled ambitiously, NBS may also impact land values and equity concerns must be proactively assessed and managed. With thoughtful, responsive planning, cities can find ways for nature and people to thrive in tandem.

Overall, while surmounting barriers to adoption remains challenging, this research highlights that successfully transitioning to NBS requires learning from experience, bringing together diverse stakeholders, adapting policies and business models. This research highlights valuable strategies that help make this transition happen. With intensive effort across sectors to implement the strategies outlined, the barriers to NBS can be overcome, paving the way for more sustainable, climate resilient and regenerative cities worldwide.

APPENDIX

Appendix I: Schcematic overview of one example of a coding process:



Appendix II: Full List of Case Studies

Name of case study	Continent	Primary intervention type	Scale	CCA goal	Year started – Year implemented	Main Link	Additional Links
A flood and heat proof green Emscher valley, Germany	Europe	Sustainable Drainage Systems (SuDS)	City	Water	2016-2019	https://oppla.eu/casestudy/19175	https://www.architecture.com/awards-and-competitions-landing-page/awards/riba-regional-awards/riba-south-west-award-winners/2018/brunel-building-southmead-hospital
Abu Dhabi Blue Carbon Demonstration Project	Asia	Mangrove restoration	City	Water	1992-2022	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/a-flood-and-heat-proof-green-emscher-valley-germany	http://www.future-cities.eu,http://www.eglv.de/emschergenossenschaft
Araucárias Square~ rain garden and pocket forest	America	Sustainable Drainage Systems (SuDS)	Site	Heat	2012-2013	https://www.grida.no/activities/324	https://www.grida.no/publications/181
Bath Quays Waterside Park	Europe	Urban parks	Regional	Heat	2017-2017	https://oppla.eu/casestudy/20079	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-araucarias.pdf
Bay at Norikus	Europe	Urban forest	Neighborhood	Heat and Biodiversity	Not stated-Not stated	https://oppla.eu/casestudy/19137	http://www.bathnes.gov.uk/sites/default/files/bath_frm_tech_summary_for_core_strategy-final.pdf and

							http://www.bathnes.gov.uk/sites/default/files/bath_quays_waterside_consultation.pdf
Beijing Plain Area Afforestation Programme (BPAP)	Asia	Urban forest	Regional	Heat and Biodiversity	2017-2018	https://una.city/nbs/nurnberg/bay-norikus	https://www.nuernberg.de/internet/stadtportal/wasserwelt_woehrdersee.html
Bishan-Ang Mo Kio Park & Kallang River Restoration	Asia	Urban forest, river restoration	Neighborhood	Heat	2012-2015	https://networknature.eu/casestudy/22591	https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5dc8c1ee2&appId=PPGMS
Brasília Serrinha do Paranoá waters project	America	Blue green infrastructure (droughts and flooding)	Regional	Water	2009-2012	https://una.city/nbs/singapore/bishan-ang-mo-kio-park-kallang-river-restoration	https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/54/e3sconf_icaeer2020_05060.pdf
Brazil Water Program	America	Urban forest fpr SuDS	Regional	Water	2011-2019	https://networknature.eu/casestudy/20068	https://circulars.iclei.org/wp-content/uploads/2021/03/Brasilia_ICLEI-Circulars-case-study_Final-1.pdf
Bristol Habourside	Europe	Sustainable Drainage Systems (SuDS)	Site	Heat	2010-2019	https://networknature.eu/casestudy/26184	https://www.wwf.org.br/?60742/Restaurao-ecolgica-no-Brasil-desafios-e-oportunidades
Building Climate Change Resilience	Asia	Green infrastructure	Regional	Water	Not stated-Not stated	https://oppla.eu/casestudy/19160	www.grant-associates.uk.com/2578/grant-associates-completes-sustainable-public-realm-

							landscape-bristols-historic-waterfront
Building coastal resilience for Muanda's communities	Africa	Blue infrastructure	Regional	Heat	2015-2022	https://una.city/nbs/battambang/building-climate-change-resilience	https://www.adb.org/sites/default/files/publication/215721/nature-based-solutions.pdf
Building community-driven vertical gardens	Africa	Vertical gardens (water)	Neighborhood	Heat and Biodiversity	2015-2022	https://www.thegef.org/projects-operations/projects/5280	https://una.city/nbs/muanda/building-coastal-resilience-muandas-communities
Building fire resilience using recycled water in Riba-Roja de Túria, Spain	Europe	Sustainable Drainage Systems (SuDS)	Regional	Water	2014-2018	https://una.city/nbs/agege/building-community-driven-vertical-gardens	https://iopscience.iop.org/article/10.1088/1755-1315/685/1/012017/pdf
Cabo frio Seashore ecosystem restoration	America	Restoring Sandunes for flooding	City	Heat	2019-2021	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/building-fire-resilience-using-recycled-water-in-riba-roja-de-turia-spain	https://proyectoguardian.com
Campinas~ ecological strategic plans for biodiversity and water protection	America	Green corridors	Neighborhood	Heat	2016-2018	https://networknature.eu/casestudy/20077	https://networknature.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-seashore.pdf

Green Ventilation Corridors	Europe	Green corridor	Regional	Heat	2017-2022 (Stage 1)	https://networknature.eu/casestudy/20065	https://connectingnature.eu/oppla-case-study/20065 https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-campinas.pdf
Inspiring Water Action in Torne (IWAIT)	Africa	Bioswales, rain garden green streets Sustainable Drainage Systems (SuDS)	Regional	Heat	2008-2011	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/catchment-management-approach-to-flash-flood-risks-in-glasgow	https://waterprojectsonline.com/wp-content/uploads/case_studies/2013/White-Cart-Flood-Prevention-Scheme-2013.pdf?looking=case-study,https://www.ceequal.com/case-studies/white-cart-flood-prevention-scheme/,https://www.mgsdp.org/index.aspx?articleid=22121
Elderberry Walk	Europe	Rain Garden Climate smart/resilient agriculture	City	Heat	2013-2017	https://una.city/nbs/bangkok/chulalongkorn-centenary-park	https://www.bangkokpost.com/life/social-and-lifestyle/1578442/seeing-green-is-believing
Warsaw green network	Europe	Green roof / green wall	Neighborhood	Water	Not stated-2015	https://una.city/nbs/oslo/citytree	https://www.nina.no/Portals/NINA/Bilder%20og%20dokumenter/Prosjekter/Urban%20EEA/NINA%20Report%201453%20-%20Accounting%20for%20trees.pdf
Case Study 23-River Somer Channel Enhancement	Europe	Bioswales, rain garden green streets Sustainable	City	Heat	2013-2016	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/climate-	http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPag

		Drainage Systems (SuDS)				proofing-social-housing-landscapes-2013-groundwork-london-and-hammersmith-fulham-council	e&n_proj_id=4752,http://www.urbanclimateproofing.london
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region	Asia	Rain Garden Climate smart/resilient agriculture	Neighborhood	Water	2019-2022	https://una.city/nbs/windhoek/climate-resilient-community-onyika-settlement	https://acdi.uct.ac.za/sites/default/files/content_migration/acdi_uct_ac_za/1205/files/Mainstreaming%2520ecosystem-based%2520adaptation%2520into%2520climate%2520resilience%2520strategies%2520for%2520informal%2520settlements%2520in%2520Windhoek%252C%2520Namibiadocx%2520%25282%2529.pdf
Catchment management approach to flash flood risks in Glasgow	Europe	Sustainable Drainage Systems (SuDS)	Regional	Water	2018-2022	https://networknature.eu/casestudy/26849	https://networknature.eu/sites/default/files/uploads/sincere-findings02club-grey-horse.pdf
Chulalongkorn Centenary Park	Asia	Green Blue inftastructure	Neighborhood	Water	2009-2013	https://casestudies.naturebasedsolutionsinitiative.org/casestudy/coastal-mangrove-afforestation-using-a-community-ecosystem-based-	https://www.weadapt.org/placemarks/maps/view/138 ; https://www.weadapt.org/sites/weadapt.org/files/legacy-new/placemarks/files/53022a4989f5fbangladesh-coastal-afforestation-november-2011.pdf ; https://unfccc.int/climate-

						adaptation-approach/	action/momentum-for-change/activity-database/community-based-adaptation-to-climate-change-through-coastal-afforestation-cbacc-cf-project-in-bangladesh
CityTree	Europe	Green roof / green wall	City	Heat and Biodiversity	Not stated-2018	https://networknature.eu/casestudy/22657	https://www.adb.org/sites/default/files/publication/705086/100-climate-actions-cities-asia-pacific.pdf
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council	Europe	Water Management	Regional	Water	2017-2022	https://una.city/nbs/islamabad/conservation-and-reforestation-margalla-hills-national-park	https://documents1.worldbank.org/curated/en/547111468774907440/pdf/multi-page.pdf
Climate-resilient community~ Onyika Settlement	Africa	Street trees , green walls, gardens	Neighborhood	Heat	1994-2016	https://networknature.eu/casestudy/20056	https://networknature.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-curitiba.pdf
Club GREY HORSE – Providing multiple ecosystems	Asia	Urban forest (heat)	City	Heat	1972-2016	https://oppla.eu/casestudy/20056	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-curitiba.pdf

services by forest renters							
Coastal mangrove restoration using a community ecosystem-based adaptation approach	Asia	Coastal afforastation (flooding)	City	Heat and Water	2014-2022	https://una.city/nbs/victoria/ecosystem-based-adaptation-climate-change	https://www.adaptation-fund.org/projects-document-view/?URL=https://pubdocs/en/273241532122854369/19-RESUBMISSION-AF-Proposal-EBA-Seychelles-8Oct12-1.pdf
Coastal towns in Viet Nam prepare for a warmer future	Asia	Sustainable Drainage Systems (SuDS)	City	Biodiversity	2014-2017	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/eea-grants-supporting-the-city-of-bratislava-to-implement-climate-adaptation-measures	http://eeagrants.org/project-portal/project/SK02-0005,http://www.resin-cities.eu/resources/cityreports/bratislava
Conservation and Reforestation of the Margalla Hills National Park	Asia	Urban forest	Regional	Heat and Biodiversity	Not stated-Not stated	https://oppla.eu/casestudy/19135	https://networknature.eu/casestudy/19135 ; and https://eprints.glos.ac.uk/7091/9/7091%20Jones%20(2019)%20Nature%20based%20solutions.pdf; and https://gib-foundation.org/wp-content/uploads/2021/02/DriversBarriers_NBS.pdf

Curitiba Barigui watershed restoration	America	Urban heat island (urban parks)	Regional	Heat and Biodiversity	2012-2018	https://geagindia.wordpress.com/2016/01/18/a-city-grows-food-on-the-fringes-flood-proofs-itself/	https://e-lib.iclei.org/formative-evaluation-report-enhancing-climate-resilience-of-gorakhpur-by-buffering-floods-through-climate-resilient-peri-urban-agriculture/ ; and https://geagindia.org/annual-report.php? ; and https://ruaf.org/assets/2019/12/Enhancing-climate-resilience-of-Gorakhpur-by-buffering-floods-through-peri-urban-agriculture-final1.pdf
Ecosystem-based Adaptation to Climate Change	Africa	Green-blue infrastructure	Regional	Heat	2011-2015	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/environment-friendly-urban-street-design-for-decentralized-ecological-rainwater-management-in-ober-grafendorf-lower-austria	http://zenebio.at/buchenstrasse-obergrafendorf/,http://gemeinde.ober-grafendorf.at/projekte/oekostrasse/,http://niederoesterreich.klimabuendnis.at/gemeinden-projektnachlese/wandelbares-mostviertel-fit-in-die-klimazukunft-das-projekt,https://www.cipra.org/en/cipra/international/projects/completed/C3-Alps
EEA grants supporting the city of Bratislava to	Europe	Green Roofs/ Green Walls	City	Water	2018-2019	https://oppla.eu/casestudy/19706	https://www.nature.scot/sites/default/files/2020-12/Publication%202020%20-%20SNH%20Annual%20Report

implement climate adaptation measures							%20and%20Accounts%202019-20.pdf
Embleton Road SuDS, Bristol	Europe	Sustainable Drainage Systems (SuDS)	City	Water	2015-2019	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/flood-protection-in-the-upper-vistula-river-basin-grey-and-green-measures-implemented-in-the-sandomierz-area	https://odrapcu.pl/en/project-ovfmp/about-project-ovfmp/upper-vistula/,https://www.eea.europa.eu/publications/green-infrastructure-and-flood-management
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture	Asia	Rain Garden Climate smart/resilient agriculture	Regional	Heat	2014-n/a	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/four-pillars-to-hamburg2019s-green-roof-strategy-financial-incentive-dialogue-regulation-and-science	http://www.hamburg.de/gruendach,http://www.ifbhh.de/gruendachfoerderung,https://www.hamburg.de/information-in-english/
Environment-friendly urban street design for decentralized ecological rainwater	Europe	Water Management (Green Corridor)	City	Water	2010-2013	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/gaia-green-area-inner-city-agreement-to-	http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3752,http://www.lifegaia.eu

management in Ober-Grafendorf, Lower Austria						finance-tree-planting-in-bologna	
Fernbrae Meadows Urban Park	Europe	Urban parks	City	Water	2006-2018	https://networknature.eu/casestudy/17482	https://networknature.eu/sites/default/files/uploads/valuescasestudyreducingsedimentationindonesiacd.pdf
Flood protection in the Upper Vistula river basin~ grey and green measures implemented in the Sandomierz area	Europe	Sustainable Drainage Systems (SuDS)	City	Water	Not stated-Not stated	https://oppla.eu/casestudy/19193	https://www.biodiversityinplanning.org/wp-content/uploads/2019/04/Gloucester-Service-Station-final.pdf
Four pillars to Hamburg's Green Roof Strategy~ financial incentive, dialogue, regulation, and science	Europe	Green Roofs/Green Corridor	Regional	Water	2011-2013	https://una.city/nbs/batticaloa/green-belt-costal-protection	http://asialedspartnership.org/images/alp-publications/MLCG-CoP-CRCAP-case-study-Nov2020.pdf
GAIA - Green Area Inner-city Agreement to finance tree	Europe	Urban park	City	Water	1998-2022	https://una.city/nbs/nur-sultan/green-belt-nur-sultan-city	https://unece.org/sites/default/files/2021-01/Nur-Sultan%20City%20Profile_compressed_E.pdf

planting in Bologna							
GIZ ValuES - Rewarding farmers for reducing sedimentation, Indonesia	Asia	Tree canopy (flooding)	City	Water	Not stated-2015	https://oppla.eu/casestudy/18419	https://una.city/nbs/barcelona/urban-green-corridor; and https://naturvation.eu/sites/default/files/barcelona_snapshot.pdf
Gloucester Services	Europe	Sustainable Drainage Systems (SuDS)	Site	Water	Not stated-2012	https://oppla.eu/casestudy/19519	https://urbannext.net/aime-cesaire-primary-school/
Green belt for costal protection	Asia	Green Belt (flooding)	Regional	Heat	2014-2018	https://una.city/nbs/blimbingsari/green-roof-banyuwangi-international-airport	https://www.sciencedirect.com/science/article/pii/S0264275122001329
Green Belt of Nur-Sultan city	Asia	Green Belt	Regional	Heat and Biodiversity	2005-2007	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/green-roofs-in-basel-switzerland-combining-mitigation-and-adaptation-measures-1	http://www.greenroofs.org,http://urbanhabitats.org/v04n01/wildlife_full.html,http://www.urbanhabitats.org/v04n01/wildlife_pdf.pdf
Green corridor in Passeig de Sant Joan,	Europe	Green corridor	Regional	Biodiversity	2015-2020	https://una.city/nbs/beira/green-urban-infrastructure-municipality-beira	https://www.preventionweb.net/publication/mozambique-upscaling-nature-based-flood-

Barcelona (ENABLE project)							protection-mozambiques-cities-urban-flood-and
Green bond for infrastructure financing in Cape Town, South Africa	Africa	Green Corridor	City	Heat and Biodiversity	2017-2022	https://citiesclimatefinance.org/financial-instruments/cases/green_bond_for_infrastructure_financing_in_cape_town_south_africa/	https://www.undrr.org/media/48285
Green Roof of Aimé Césaire School Complex	Europe	Green roof / green wall	Site	Biodiversity	1998-2014	https://una.city/nbs/stuttgart/green-ventilation-corridors	https://unfccc.int/files/parties_observers/submissions_from_observers/application/pdf/778.pdf ; and https://www.preventionweb.net/files/27772_dasgesamtenbf1-63.pdf
Green Roof of Banyuwangi International Airport	Asia	Green Roof	Neighborhood	Water	Not stated-Not stated	https://oppla.eu/casestudy/19153	https://www.hta.co.uk/project/hanham-hall
Green roofs in Basel, Switzerland~ combining mitigation and adaptation measures	Europe	Green roofs	City	Water	2018-2022	https://networknature.eu/casestudy/21696	https://wedocs.unep.org/handle/20.500.11822/28927; https://www.greenclimate.fund/document/heritage-colombia-heco-maximizing-contributions-sustainably-managed-landscapes-colombia

Green Urban Infrastructure in the municipality of Beira	Africa	Green blue infrastructure (water and heat)	City	Water	2011-2020	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/implementation-of-the-integrated-master-plan-for-coastal-safety-in-flanders	https://www.afdelingkust.be/nl/masterplan-kustveiligheid
Hanham Hall	Europe	Urban parks	Neighborhood	Water	2012-2015	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/implementation-of-the-vitoria-gasteiz-green-urban-infrastructure-strategy	http://www.vitoria-gasteiz.org/wb021/http/contenidosEstaticos/adjuntos/es/44/11/44411.pdf,http://www.vitoria-gasteiz.org/wb021/http/contenidosEstaticos/adjuntos/es/72/64/47264.pdf
Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals	America	Blue green infrastructure	Regional	Water	2016-2017	https://una.city/nbs/doncaster/inspiring-water-action-torne-iwait	https://www.therrc.co.uk/sites/default/files/projects/26_torne.pdf ; and https://www.ywt.org.uk/sites/default/files/2019-09/River%20Torne%20Catchment%20Plan.pdf

Implementation of the integrated Master Plan for Coastal Safety in Flanders	Europe	Sustainable Drainage Systems (SuDS) Flooding	City	Heat	2008-2015	https://una.city/nbs/dhaka/integrated-development-hatirjheel-area	https://www.sciencepolicyjournal.org/uploads/5/4/3/4/5434385/islam_et_al_jspg_18.2.pdf
Implementation of the Vitoria-Gasteiz Green Urban Infrastructure Strategy	Europe	Water Management, Urban Heat Island	Site	Heat	2000-2011	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/isar-plan-2013-water-management-plan-and-restoration-of-the-isar-river-munich-germany	https://restorerivers.eu/wiki/index.php?title=Case_study%3AIsar-Plan,https://www.yumpu.com/en/document/read/3768185/a-new-lease-of-life-for-the-isar-river-wasserwirtschaftsamt-munchen,https://panorama.solutions/en/solution/isar-plan-improving-flood-protection-and-recreational-opportunities-redesigning-isar
Integrated Development of the Hatirjheel Area	Asia	Blue infrastructure	Neighborhood	Heat	Not stated-Not stated	https://networknature.eu/casestudy/18030	https://ceowatermandate.org/wp-content/uploads/2017/11/BAFWAC_-_Volkswagen_11.3.pdf
Isar-Plan – Water management plan and restoration of the Isar river, Munich (Germany)	Europe	Water Management	City	Water	2007-2022	https://una.city/nbs/nairobi/kiberas-vertical-farms	https://www.urban-response.org/system/files/content/resource/files/main/pascal-a-garden-in-a-sack-experiences-in-kibera.pdf

Izta Popo - Replenishing Groundwater through Reforestation in Mexico	America	Urban forest	City	Biodiversity	2012-2022	https://una.city/nbs/chiang-rai/kok-river-ecological-restoration	https://www.adb.org/sites/default/files/publication/215721/nature-based-solutions.pdf
Kibera's vertical farms	Africa	Green walls	Neighborhood	Heat and Biodiversity	2018-2021	https://www.darwininitiative.org.uk/project/DAR25014/	https://www.darwininitiative.org.uk/documents/DAR25014/26008/25-014%20FR%20-%20Edited.pdf
Kok River Ecological Restoration	Asia	Green infrastructure	Regional	Heat and Biodiversity	2010-2012	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/living-in-a-tree-house-in-torino-italy-combining-adaptation-and-mitigation-measures-to-improve-comfort	http://www.lineeverdi.com/portfolio/25-verde/#,http://www.lucianopia.it/opere-e-progetti/2007-2012-25-green-25-verde/
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem	Africa	Agroforestry	City	Biodiversity	2017-2022	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/mainstreaming-adaptation-in-water-management-for-flood-protection-in-isola-vicentina	http://www.comune.isola-vicentina.vi.it

Living in a tree house in Torino (Italy)~ combining adaptation and mitigation measures to improve comfort	Europe	Urban Heat Island (Green Roof/ Green Wall)	Site	Heat and Biodiversit y	2013-2018	https://landportal.o rg/node/101412	https://chemonics.com/wp-content/uploads/2019/02/CCA P_Final-Report_Feb-2019.pdf
Mainstreaming adaptation in water management for flood protection in Isola Vicentina	Europe	River restoration and/or realignment	Regional	Water	Not stated-Not stated	http://nrcsolutions. org/maywood-avenue-stormwater-volume-reduction-project-toledo-oh/	http://www.ohiowea.org/docs /01_CSO_Vol_Reduct_Green.p df
Mangroves Restoration for Climate Adaptation	Africa	Green infrastructur e (flooding(	Regional	Heat and Biodiversit y	2014-Not stated	https://oppla.eu/ca sestudy/19707	https://www.nature.scot/fundi ng-and-projects/green-infrastructure-strategic-intervention/projects/gi-fund-projects/middlefield-greenspace-and-regeneration-project
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio	America	Bioswales, rain garden green streets Sustainable Drainage Systems (SuDS)	Neighborh ood	Heat and Water	Not stated-2012	https://una.city/nbs /lisboa/monsanto-green-corridor	https://connectingnature.eu/o ppla-case-study/19462

Middlefield Greenspace	Europe	Urban parks	City	Water	Not stated-Not stated	https://oppla.eu/casestudy/19011	http://worldgreeninfrastructurenetwork.org/wp-content/uploads/2021/05/Book_3_Multifuctional-Urban-Green-Infrastructure_Komplett_2019.pdf
Monsanto green corridor	Europe	Green corridor	Regional	Water	2012-2020 (city) 2030 (regional)	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/multifunctional-water-management-and-green-infrastructure-development-in-an-ecodistrict-in-rouen	http://www.future-cities.eu/,http://www.rouen-normandie-amenagement.fr,http://www.rouen.fr/luciline-rive-de-seine
Multifunctional urban greening in Malmö, Sweden	Europe	Green roof / green wall	Neighborhood	Biodiversity	2018-2020	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/natural-water-retention-measures-in-the-altovicentino-area-italy	http://www.lifebeware.eu/en
Multifunctional water management and green infrastructure	Europe	Sustainable Drainage Systems (SuDS), Water	City	Heat	2014-2019	https://networknature.eu/casestudy/23355	https://www.conexusnbs.com/case-studies

development in an eco-district in Rouen		Management					
Natural Water Retention Measures in the Altovicentino area (Italy)	Europe	Water Management (droughts and flooding)	City	Heat and Water	2012-2015	https://una.city/nbs/doncaster/nia-dearne-valley-green-heart-eco-vision	https://publications.naturalengland.org.uk/publication/5542385517854720
Nature-Based Solutions as integral and multiscale responses to social and environmental challenges in Lima, Peru	America	Blue green infrastructure for Sustainable drainage system SuDS	Regional	Heat and Water	2018-2021	https://una.city/nbs/kigali/nyandungu-wetland-eco-park	https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/publications/Planning%20docs/Nyandungu%20wetland%20plan_2012.pdf
NIA Dearne Valley Green Heart & Eco-vision	Europe	Watershed restoration	Regional	Heat and Water	2019-2021	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/paris-oasis-schoolyard-programme-france	https://www.paris.fr/pages/les-cours-oasis-7389,https://www.uia-initiative.eu/en/uia-cities/paris-call3,https://www.eea.europa.eu/publications/who-benefits-from-nature-in/oasis-school-grounds-programme-in,https://ec.europa.eu/regional_policy/en/projects/France/oasis-in-paris-greening-the-city-and-reversing-climate-change-one-schoolyard-at-a-

							time,https://www.caue75.fr/ateliers-a-l-ecole,https://oppla.eu/casestudy/18474
Nyandungu Wetland Eco-park	Africa	Wetland (SuDS)	Regional	Biodiversity	2002-2007	https://networknature.eu/casestudy/20075	https://oppla.eu/casestudy/20075 ; https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-petropolis.pdf
Paris Oasis Schoolyard Programme, France	Europe	Urban park	Site	Biodiversity	2016-2018	https://networknature.eu/casestudy/21682	https://use.metropolis.org/system/images/3127/original/pln26_eng.pdf; https://www.learning.uclg.org/ ; https://use.metropolis.org/case-studies/portoviejos-linear-park
Petrópolis~ biological waste-water treatment	America	Constructed wetland for flooding and waste	City	Water	2012-2013	https://networknature.eu/casestudy/23366	https://www.urbanet.info/nature-based-solutions-quito/
Portoviejo's Linear Park	America	Green corridors	City	Water	2018-2021	https://una.city/nbs/jakarta/rain-garden-and-bioswales-central-jakarta	https://www.sciencedirect.com/science/article/pii/S0264275122001329
Quito_ Urban Agriculture as Nature Based Solution for facing Climate	America	Urban gardens	Neighborhood	Heat	2017-2019	https://cbc.iclei.org/inclusive-urban-park-replaces-informal-waste-dumping-site-in-	https://una.city/nbs/addis-ababa/ras-mekonnen-urban-park

Change and Food Sovereignty						addis-ababa-ethiopia/whatsapp-image-2019-09-03-at-11-49-12/	
Rain Garden and Bioswales in Central Jakarta	Asia	Bioswales, rain garden green streets Sustainable Drainage Systems (SuDS)	Neighborhood	Water	2012-Not stated	https://networknature.eu/casestudy/20074	https://oppla.eu/casestudy/20074
Ras Mekonnen Urban Park	Africa	Urban Park (heat and flooding)	Neighborhood	Water	Not stated-2007	https://oppla.eu/casestudy/19183	https://www.susdrain.org/case-studies/case_studies/redland_green_school_bristol.html
Recreio green corridor	America	Green corridor	Regional	Heat	2015-2018	https://www.darwininitiative.org.uk/project/DAR22001/	https://www.darwininitiative.org.uk/documents/DAR22015/24529/22-015%20FR%20edited.pdf
Redland green school	Europe	Sustainable Drainage Systems (SuDS)	Site	Water	1990-2000	https://networknature.eu/casestudy/20067	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-mutirao.pdf
Rescuing and restoring the native flora of Robinson Crusoe Island	America	Native plant restoration, seed banks	City	Heat and Water	Not stated-Not stated	https://oppla.eu/casestudy/19174	https://beta.bathnes.gov.uk/sites/default/files/somer_valley_inc_main_modifications.pdf and; https://beta.bathnes.gov.uk/sites/default/files/somer_valley_inc_main_modifications.pdf and;

							www.therrc.co.uk/sites/default/files/projects/p1710.pdf
Rio de Janeiro reforestation collective action	America	Urban forest	City	Heat and Water	2012-2016	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/room-for-the-river-waal-2013-protecting-the-city-of-nijmegen	https://www.urbanclimateadaptation.net/ezine1/,http://www.hnsland.nl/nl/projects/ruimte-voor-de-waal,https://www.youtube.com/watch?v=-2TE2eSV77k&feature=youtu.be,https://goexplorer.org/nijmegen-embracing-the-river-to-combat-flooding/
Medellín Manifesto: Learning Cities for Inclusion	America	Green Infrastructure	City	Heat and Water	2015-2020	https://unesdoc.unesco.org/ark:/48223/pf0000371128	https://unesdoc.unesco.org/ark:/48223/pf0000371128
Room for the River Waal – protecting the city of Nijmegen	Europe	River restoration and/or realignment	City	Water	2016-2017	https://networknature.eu/casestudy/20079	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-araucarias.pdf
Sao Paolo Araucárias Square rain garden and pocket forest	America	Pocket forest	Neighborhood	Heat and Biodiversity	2015-2017	https://networknature.eu/casestudy/20069	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-jaguare.pdf
Sao paolo jaguare creek restoration	America	Green cover Sustainable Drainage	City	Water	2013-2015	https://networknature.eu/casestudy/20078	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-springs-square.pdf

		Systems (SuDS)					
Sao Paolo Springs Square nurturing urban waters	America	Blue green infrastructure	City	Water	2013-Not stated	https://oppla.eu/casestudy/19379	https://eprints.gla.ac.uk/243666/1/243666.pdf
Schansbroek, Genk – brownfield regeneration	Europe	Urban parks	Neighborhood	Heat	2013-2015	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/social-vulnerability-to-heatwaves-2013-from-assessment-to-implementation-of-adaptation-measures-in-kosice-and-trnava-slovakia	http://www.kri.sk/gb/home/
Social vulnerability to heatwaves – from assessment to implementation of adaptation measures in Košice and Trnava, Slovakia	Europe	Water Management for Heat waves	Site	Water	2000-2007	https://networknature.eu/casestudy/23346	https://iki-small-grants.de/project/nature-based-solutions-for-urban-resilience-in-colombia/ ; https://oppla.eu/casestudy/23346

Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia	America	Blue green infrastructure	City	Heat and Water	2013-not stated	https://oppla.eu/casestudy/20078	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-springs-square.pdf
Southmead Hospital Brunel Building	Europe	Sustainable Drainage Systems (SuDS)	Site	Heat and Biodiversity	2013-2014	https://una.city/nbs/johannesburg/suds-diepsloot	https://pdfs.semanticscholar.org/00b4/d60e97cea504c1e288d3c2ac6e3789249473.pdf?_ga=2.178275492.1829948679.1650970187-154202399.1650546662
Springs Square~ nurturing urban waters	America	Urban parks	City	Heat and Water	2012-2019	https://una.city/nbs/dubai/sustainable-residential-complex-development	https://www.nature.org/content/dam/tnc/nature/en/documents/NBSWhitePaper.pdf
SuDS in Diepsloot	Africa	Street trees for water	Neighborhood	Heat and Biodiversity	2016-2019	https://www.darwininitiative.org.uk/project/DAR23019/	https://www.darwininitiative.org.uk/documents/DAR23019/24552/23-019%20FR%20edited.pdf
Sustainable Residential Complex Development	Asia	Green Blue infrastructure	Neighborhood	Biodiversity	2008-2012	https://una.city/nbs/tianjin/eco-valley-sino-singapore-tianjin-eco-city	https://naturvation.eu/sites/default/files/result/files/innovation_pathways_directory_0.pdf

Sustaining biodiversity, livelihoods and culture in PNG's montane forests	Asia	Climate smart/resilient agriculture	City	Heat	2012-2015	https://naturvation.eu/location/europe/fr/montpellier.html	https://una.city/nbs/montpellier/green-and-blue-urban-network-project
The Eco-Valley of the Sino-Tianjin Eco City	Asia	Green Belt	Regional	Heat	2013-2014	https://www.urbanagendaplatform.org/best-practice/multifunctional-and-productive-use-greenways-city-bobo-dioulasso	https://una.city/nbs/bobo-dioulasso/greenways-bobo-dioulasso
The Greenways of Bobo-Dioulasso	Africa	Urban forestry (flood and heat)	Regional	Heat	2012-2015	https://networknature.eu/casestudy/23367	https://www.jstor.org/stable/26937762
River Landing Miami	America	Green corridors	City	Water	2013-2022	https://www.aslaflorida.org/page-18137?emulatemode=2	https://www.riverlandingmiami.com/
The refurbishment of Gomeznarro park in Madrid focused on storm water retention	Europe	Urban park	City	Heat and Water	2014-2017	https://www.weadapt.org/placemarks/maps/view/31826	https://www.ecomena.org/green-roof-arab/ ; and; https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Egypt/1/Egyptian%20INDC.pdf ; and; https://www.weadapt.org/sites/weadapt.org/files/2017/july/

							barriers_and_opportunities_rooftop_greenhouses.2012.pdf
Urban Agriculture in the Greater Cairo Region. An Example of Rooftop Farming	Africa	Rooftop farming	Neighborhood	Heat	2012-2015	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/urban-river-restoration-a-sustainable-strategy-for-storm-water-management-in-lodz-poland	http://www.en.arturowek.pl,https://uml.lodz.pl/ekoportal
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland	Europe	River restoration and/or realignment	City	Water	2014-2018	https://renature-project.eu/compendium/113	https://www.weadapt.org/sites/weadapt.org/files/2017/july/cca_giz_best_practices_4_urban_agriculture.pdf
Urban stormwater management in Augustenborg, Malmö	Europe	Green roofs, Green Walls	City	Heat and Biodiversity	1998-2002	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/urban-storm-water-management-in-augustenborg-malmo	https://naturvation.eu/location/europe/se/malmo.html,https://malmo.se/Welcome-to-Malmo/Sustainable-Malmo/Sustainable-Urban-Development/Augustenborg-Eco-City/The-Green-City.html,https://smartcitysweden.com/best-practice/329/eco-city-augustenborg-creating-an-

							attractive-and-resilient-district/
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam	Europe	Urban Farming	City	Heat and Water	2005-2007	https://climate-adapt.eea.europa.eu/en/metadata/case-studies/vrijburcht-a-privately-funded-climate2013proof-collective-garden-in-amsterdam	http://www.vlugp.nl/projecten/binnentuin-vrijburcht/,https://www.rainproof.nl/vrijburcht-binnentuin,http://www.vrijburcht.com
Yanweizhou Wetland Park-A resilient landscape, Jinhua	Asia	Sustainable Drainage Systems (SuDS)	City	Heat and Biodiversity	Not stated-2014	https://oppla.eu/casestudy/18018	https://landezine.com/a-resilient-landscape-yanweizhou-park-in-jinhua-city-by-turenscape/

Appendix III: List of Categorial Variables

Continent	Scale
Asia	Site
Europe	Neighborhood
Africa	City
America	Regional

Appendix IV: Barriers across case studies

Policy Barriers
Municipal policies
Abu Dhabi Blue Carbon Demonstration Project
Beijing Plain Area Afforestation Programme (BPAP)
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Cabo frio Seashore ecosystem restoration
Campinas~ ecological strategic plans for biodiversity and water protection
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Conservation and Reforestation of the Margalla Hills National Park
Ecosystem-based Adaptation to Climate Change
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Four pillars to Hamburg’s Green Roof Strategy~ financial incentive, dialogue, regulation, and science
Green belt for costal protection
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Green roofs in Basel, Switzerland~ combining mitigation and adaptation measures
Green Urban Infrastructure in the municipality of Beira
Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals

Isar-Plan – Water management plan and restoration of the Isar river, Munich (Germany)
Kibera's vertical farms
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mangroves Restoration for Climate Adaptation
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Monsanto green corridor
Natural Water Retention Measures in the Altovicentino area (Italy)
Nature-Based Solutions as integral and multiscale responses to social and environmental challenges in Lima, Peru
Nyandungu Wetland Eco-park
Portoviejo's Linear Park
Ras Mekonnen Urban Park
Rescuing and restoring the native flora of Robinson Crusoe Island
SuDS in Diepsloot
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The Greenways of Bobo-Dioulasso
The importance of Nature-Based Solutions
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam
Yanweizhou Wetland Park- A resilient landscape, Jinhua

National policies

A flood and heat proof green Emscher valley, Germany
Abu Dhabi Blue Carbon Demonstration Project
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Bishan-Ang Mo Kio Park & Kallang River Restoration
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities

Building community-driven vertical gardens
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
CityTree
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Conservation and Reforestation of the Margalla Hills National Park
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Fernbrae Meadows Urban Park
Flood protection in the Upper Vistula river basin~ grey and green measures implemented in the Sandomierz area
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Green roofs in Basel, Switzerland~ combining mitigation and adaptation measures
Implementation of the Vitoria-Gasteiz Green Urban Infrastructure Strategy
Integrated Development of the Hatirjheel Area
Kibera's vertical farms
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mainstreaming adaptation in water management for flood protection in Isola Vicentina
Mangroves Restoration for Climate Adaptation
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Middlefield Greenspace
Multifunctional urban greening in Malmö, Sweden
Natural Water Retention Measures in the Altovicentino area (Italy)
Nyandungu Wetland Eco-park
Portoviejo’s Linear Park

Rain Garden and Bioswales in Central Jakarta
Ras Mekonnen Urban Park
Room for the River Waal – protecting the city of Nijmegen
Schansbroek, Genk – brownfield regeneration
Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia
Southmead Hospital Brunel Building
Springs Square~ nurturing urban waters
SuDS in Diepsloot
Sustainable Residential Complex Development
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The importance of Nature-Based Solutions
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland

Financial
Cost-benefit analysis
Abu Dhabi Blue Carbon Demonstration Project
Bath Quays Waterside Park
Beijing Plain Area Afforestation Programme (BPAP)
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Building fire resilience using recycled water in Riba-Roja de Túria, Spain
Case study 10- Green Ventilation Corridors
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
CityTree
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
Fernbrae Meadows Urban Park
GAIA - Green Area Inner-city Agreement to finance tree planting in Bologna
Green belt for costal protection
Green corridor in Passeig de Sant Joan, Barcelona (ENABLE project)
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira
Integrated Development of the Hatirjheel Area
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio

Middlefield Greenspace
Multifunctional urban greening in Malmö, Sweden
Nature-Based Solutions as integral and multiscale responses to social and environmental challenges in Lima, Peru
Nyandungu Wetland Eco-park
Portoviejo’s Linear Park
Rain Garden and Bioswales in Central Jakarta
Rescuing and restoring the native flora of Robinson Crusoe Island
Schansbroek, Genk – brownfield regeneration
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The importance of Nature-Based Solutions
Urban stormwater management in Augustenborg, Malmö

Demand and investment

Bath Quays Waterside Park
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Green Belt of Nur-Sultan city
Kok River Ecological Restoration
Multifunctional urban greening in Malmö, Sweden

Maintenance and monitoring

Bath Quays Waterside Park
Beijing Plain Area Afforestation Programme (BPAP)
Bishan-Ang Mo Kio Park & Kallang River Restoration
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Building community-driven vertical gardens
Case study 10- Green Ventilation Corridors
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Club GREY HORSE – Providing multiple ecosystems services by forest renters

Ecosystem-based Adaptation to Climate Change
Fernbrae Meadows Urban Park
Green Belt of Nur-Sultan city
Green Urban Infrastructure in the municipality of Beira
Integrated Development of the Hatirjheel Area
Kok River Ecological Restoration
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Multifunctional urban greening in Malmö, Sweden
Nyandungu Wetland Eco-park
Quito_ Urban Agriculture as Nature Based Solution for facing Climate Change and Food Sovereignty
Rescuing and restoring the native flora of Robinson Crusoe Island
Schansbroek, Genk – brownfield regeneration
SuDS in Diepsloot
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam

Knowledge
Development
Beijing Plain Area Afforestation Programme (BPAP)
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Case study 10- Green Ventilation Corridors
Case Study 11- Inspiring Water Action in Torne (IWAIT)
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Chulalongkorn Centenary Park
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Curitiba Barigui watershed restoration
Ecosystem-based Adaptation to Climate Change
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
Fernbrae Meadows Urban Park
GIZ ValuES - Rewarding farmers for reducing sedimentation, Indonesia
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Isar-Plan – Water management plan and restoration of the Isar river, Munich (Germany)
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Multifunctional urban greening in Malmö, Sweden

Natural Water Retention Measures in the Altovicentino area (Italy)
Portoviejo’s Linear Park
Ras Mekonnen Urban Park
Sao paolo jaguare creek restoration
Schansbroek, Genk – brownfield regeneration
Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia
Southmead Hospital Brunel Building
SuDS in Diepsloot
Sustainable Residential Complex Development
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The importance of Nature-Based Solutions

Performance evidence

Beijing Plain Area Afforestation Programme (BPAP)
Bishan-Ang Mo Kio Park & Kallang River Restoration
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Building community-driven vertical gardens
Cabo frio Seashore ecosystem restoration
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Chulalongkorn Centenary Park
CityTree
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council
Climate-resilient community~ Onyika Settlement
Club GREY HORSE – Providing multiple ecosystems services by forest renters

Conservation and Reforestation of the Margalla Hills National Park
Curitiba Barigui watershed restoration
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Fernbrae Meadows Urban Park
Flood protection in the Upper Vistula river basin~ grey and green measures implemented in the Sandomierz area
GAIA - Green Area Inner-city Agreement to finance tree planting in Bologna
GIZ ValuES - Rewarding farmers for reducing sedimentation, Indonesia
Gloucester Services
Green belt for costal protection
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira
Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals
Integrated Development of the Hatirjheel Area
Kok River Ecological Restoration
Mainstreaming adaptation in water management for flood protection in Isola Vicentina
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Multifunctional urban greening in Malmö, Sweden
Multifunctional water management and green infrastructure development in an eco-district in Rouen
Natural Water Retention Measures in the Altovicentino area (Italy)
Nyandungu Wetland Eco-park
Portoviejo’s Linear Park
Ras Mekonnen Urban Park
Sao paolo jaguare creek restoration
Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia
SuDS in Diepsloot

Sustainable Residential Complex Development
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The importance of Nature-Based Solutions
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland
Urban stormwater management in Augustenborg, Malmö

Project Timeline

Beijing Plain Area Afforestation Programme (BPAP)
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Building community-driven vertical gardens
Campinas~ ecological strategic plans for biodiversity and water protection
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
CityTree
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
Gloucester Services
Green Roof of Aimé Césaire School Complex
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira
Integrated Development of the Hatirjheel Area
Kok River Ecological Restoration
Middlefield Greenspace
Monsanto green corridor

	Multifunctional urban greening in Malmö, Sweden
	Nyandungu Wetland Eco-park
	Rain Garden and Bioswales in Central Jakarta
	Redland green school
	Rio de Janeiro reforestation collective action
	Schansbroek, Genk – brownfield regeneration
	SuDS in Diepsloot
	Sustainable Residential Complex Development
Share the project results and progress with stakeholders and community	
	Beijing Plain Area Afforestation Programme (BPAP)
	Catchment management approach to flash flood risks in Glasgow
	EEA grants supporting the city of Bratislava to implement climate adaptation measures
	GAIA - Green Area Inner-city Agreement to finance tree planting in Bologna

Collaboration and Engagement
Lack of collaborative governance system
Bath Quays Waterside Park
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Bishan-Ang Mo Kio Park & Kallang River Restoration
Brazil Water Program
Building Climate Change Resilience
Building community-driven vertical gardens
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Climate-resilient community~ Onyika Settlement
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
Fernbrae Meadows Urban Park
Flood protection in the Upper Vistula river basin~ grey and green measures implemented in the Sandomierz area
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mangroves Restoration for Climate Adaptation
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Multifunctional urban greening in Malmö, Sweden
Natural Water Retention Measures in the Altovicentino area (Italy)

Nyandungu Wetland Eco-park
Portoviejo's Linear Park
Quito_ Urban Agriculture as Nature Based Solution for facing Climate Change and Food Sovereignty
Rescuing and restoring the native flora of Robinson Crusoe Island
Schansbroek, Genk – brownfield regeneration
SuDS in Diepsloot

Lack of Public acceptance and engagement

A flood and heat proof green Emscher valley, Germany
Abu Dhabi Blue Carbon Demonstration Project
Araucárias Square~ rain garden and pocket forest
Bath Quays Waterside Park
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Building community-driven vertical gardens
Cabo frio Seashore ecosystem restoration
Case study 10- Green Ventilation Corridors
Case Study 11- Inspiring Water Action in Torne (IWAIT)
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Catchment management approach to flash flood risks in Glasgow
Conservation and Reforestation of the Margalla Hills National Park
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture

Fernbrae Meadows Urban Park
Four pillars to Hamburg's Green Roof Strategy~ financial incentive, dialogue, regulation, and science
Gloucester Services
Green belt for costal protection
Green Belt of Nur-Sultan city
Green Roof of Banyuwangi International Airport
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mangroves Restoration for Climate Adaptation
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Middlefield Greenspace
Multifunctional urban greening in Malmö, Sweden
Nyandungu Wetland Eco-park
Portoviejo's Linear Park
Rain Garden and Bioswales in Central Jakarta
Ras Mekonnen Urban Park
Rescuing and restoring the native flora of Robinson Crusoe Island
Sao Paolo Araucárias Square rain garden and pocket forest
Sao Paolo Springs Square nurturing urban waters
Southmead Hospital Brunel Building
SuDS in Diepsloot
Sustainable Residential Complex Development
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The Eco-Valley of the Sino- Tianjin Eco City

Lack of private sector support and engagement

Bath Quays Waterside Park
Beijing Plain Area Afforestation Programme (BPAP)
Conservation and Reforestation of the Margalla Hills National Park
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio

Appendix V: Strategies across cases

Policy Strategies
Coordination and integration
Bath Quays Waterside Park
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Building community-driven vertical gardens
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
CityTree
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
GAIA - Green Area Inner-city Agreement to finance tree planting in Bologna
Green belt for costal protection
Green Urban Infrastructure in the municipality of Beira
Implementation of the integrated Master Plan for Coastal Safety in Flanders
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Multifunctional urban greening in Malmö, Sweden
Nyandungu Wetland Eco-park

Paris Oasis Schoolyard Programme, France
Portoviejo’s Linear Park
Schansbroek, Genk – brownfield regeneration
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The Eco-Valley of the Sino- Tianjin Eco City
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam
Yanweizhou Wetland Park- A resilient landscape, Jinhua

Enabling governance approaches

A flood and heat proof green Emscher valley, Germany
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Cabo frio Seashore ecosystem restoration
Campinas~ ecological strategic plans for biodiversity and water protection
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Climate-resilient community~ Onyika Settlement
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Ecosystem-based Adaptation to Climate Change
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Gloucester Services
Green Roof of Aimé Césaire School Complex
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira

Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals
Integrated Development of the Hatirjheel Area
Kok River Ecological Restoration
Middlefield Greenspace
Multifunctional urban greening in Malmö, Sweden
Nyandungu Wetland Eco-park
Portoviejo’s Linear Park
Recreio green corridor
Schansbroek, Genk – brownfield regeneration
Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia
SuDS in Diepsloot
Sustainable Residential Complex Development

Leadership

Bath Quays Waterside Park
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Case study 10- Green Ventilation Corridors
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Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
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Schansbroek, Genk – brownfield regeneration
Southmead Hospital Brunel Building
SuDS in Diepsloot
Sustainable Residential Complex Development
Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The refurbishment of Gomeznarro park in Madrid focused on storm water retention

Community focused outreach

A flood and heat proof green Emscher valley, Germany
Bay at Norikus
Beijing Plain Area Afforestation Programme (BPAP)
Brasília Serrinha do Paranoá waters project
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda’s communities
Building community-driven vertical gardens
Cabo frio Seashore ecosystem restoration
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
CityTree
Climate-resilient community~ Onyika Settlement
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Conservation and Reforestation of the Margalla Hills National Park
Ecosystem-based Adaptation to Climate Change
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture

Environment-friendly urban street design for decentralized ecological rainwater management in Ober-Grafendorf, Lower Austria
Fernbrae Meadows Urban Park
GIZ ValuES - Rewarding farmers for reducing sedimentation, Indonesia
Green belt for costal protection
Green Roof of Banyuwangi International Airport
Green Urban Infrastructure in the municipality of Beira
Integrated Development of the Hatirjheel Area
Kibera's vertical farms
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mangroves Restoration for Climate Adaptation
Middlefield Greenspace
Monsanto green corridor
Multifunctional urban greening in Malmö, Sweden
Multifunctional water management and green infrastructure development in an eco-district in Rouen
Natural Water Retention Measures in the Altovicentino area (Italy)
Nyandungu Wetland Eco-park
Portoviejo’s Linear Park
Quito_ Urban Agriculture as Nature Based Solution for facing Climate Change and Food Sovereignty
Ras Mekonnen Urban Park
Recreio green corridor
Rescuing and restoring the native flora of Robinson Crusoe Island
Sao Paolo Springs Square nurturing urban waters
Schansbroek, Genk – brownfield regeneration
Social vulnerability to heatwaves – from assessment to implementation of adaptation measures in Košice and Trnava, Slovakia
Southmead Hospital Brunel Building
Springs Square~ nurturing urban waters

SuDS in Diepsloot
Sustainable Residential Complex Development
Urban Agriculture in the Greater Cairo Region. An Example of Rooftop Farming
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam

Digital Engagement

Beijing Plain Area Afforestation Programme (BPAP)
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Cabo frio Seashore ecosystem restoration
Case study 10- Green Ventilation Corridors
Case study 13- Elderberry Walk
Catchment management approach to flash flood risks in Glasgow
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Ecosystem-based Adaptation to Climate Change
EEA grants supporting the city of Bratislava to implement climate adaptation measures
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Green Roof of Banyuwangi International Airport
Kok River Ecological Restoration
Mainstreaming adaptation in water management for flood protection in Isola Vicentina
Mangroves Restoration for Climate Adaptation
Nyandungu Wetland Eco-park
Portoviejo's Linear Park
Quito_ Urban Agriculture as Nature Based Solution for facing Climate Change and Food Sovereignty
Socio-ecological networks_ NBS to integrate nature, urban planning and social appropriation in Bogota, Colombia
SuDS in Diepsloot
Sustainable Residential Complex Development
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland

Hands-on involvement

A flood and heat proof green Emscher valley, Germany
Abu Dhabi Blue Carbon Demonstration Project
Beijing Plain Area Afforestation Programme (BPAP)
Brazil Water Program
Building Climate Change Resilience
Building coastal resilience for Muanda's communities
Building community-driven vertical gardens
Building fire resilience using recycled water in Riba-Roja de Túria, Spain
Cabo frio Seashore ecosystem restoration
Case study 10- Green Ventilation Corridors
Case Study 11- Inspiring Water Action in Torne (IWAIT)
Case study 13- Elderberry Walk
Case Study 23- River Somer Channel Enhancement
Case Study 31- A socio-economic approach to Urban Rooftop farming in the Greater Cairo Region
Climate-Proofing Social Housing Landscapes – Groundwork London and Hammersmith & Fulham Council
Club GREY HORSE – Providing multiple ecosystems services by forest renters
Conservation and Reforestation of the Margalla Hills National Park
Ecosystem-based Adaptation to Climate Change
Embleton Road SuDS, Bristol
Enhancing climate resilience of Gorakhpur by buffering floods through climate-resilient peri-urban agriculture
Fernbrae Meadows Urban Park
GAIA - Green Area Inner-city Agreement to finance tree planting in Bologna
Gloucester Services
Green belt for costal protection
Green Belt of Nur-Sultan city
Green Roof of Aimé Césaire School Complex
Green Urban Infrastructure in the municipality of Beira
Heritage Colombia (HECO)_ Resilient landscapes that maximizes contribution to Colombia´s mitigation and adaptation goals

Implementation of the Vitoria-Gasteiz Green Urban Infrastructure Strategy
Integrated Development of the Hatirjheel Area
Isar-Plan – Water management plan and restoration of the Isar river, Munich (Germany)
Kok River Ecological Restoration
Landscapes and Livelihoods~ Participatory Restoration of the Mt Bamboutos Ecosystem
Mangroves Restoration for Climate Adaptation
Maywood Avenue Stormwater Volume Reduction Project, Toledo, Ohio
Multifunctional urban greening in Malmö, Sweden
Nyandungu Wetland Eco-park
Portoviejo's Linear Park
Recreio green corridor
Rescuing and restoring the native flora of Robinson Crusoe Island
Sao paolo jaguare creek restoration
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Sustaining biodiversity, livelihoods and culture in PNG's montane forests
The Eco-Valley of the Sino- Tianjin Eco City
Urban river restoration~ a sustainable strategy for storm-water management in Lodz, Poland
Urban stormwater management in Augustenborg, Malmö
Vrijburcht~ a privately funded climate–proof collective garden in Amsterdam

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