Strategy Paper

Nature-based Solutions to Build

Climate Resilience in Informal Areas

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NATURE-BASED SOLUTIONS TO BUILD CLIMATE RESILIENCE IN INFORMAL AREAS
STRATEGY PAPER

United Nations Human Settlements Programme (UN-Habitat)
P.O. Box 30030 00100 Nairobi GPO KENYA
Tel: 254-020-7623120 (Central Office)
www.unhabitat.org

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Authors
Julie Greenwalt, Clara Bütow, Diana Carrillo Silva, Alex Francisco, Jeroen Klooster, Russ Dudley

Contributors
Bernhard Barth, Kim Driesen, Cerin Kizhakkethottam, Andrew Rudd, Fruzsina Straus, Raphaëlle Vignol

Design and layout: Austin Ogola

Sida

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Foreword

Ms. Maimunah Mohd Sharif
Under-Secretary-General and Executive Director, United Nations Human Settlements Programme (UN-Habitat)

As the world tackles the climate emergency, the sixth mass extinction of wildlife on Earth is accelerating. Though often addressed in silos, the climate change and biodiversity crises are intertwined. Climate change is exacerbating the decline of both habitat and species. Biodiversity loss reduces the resilience of both the planet and people and narrows response options for defeating climate change.

One of the greatest challenges for climate change adaptation is building resilience for the most vulnerable. Today, more than three billion people live in hotspots that are highly vulnerable to climate change1 and more than one billion urban dwellers live in informal areas2. Such populations often find themselves already impacted by other vulnerabilities.

There is an urgency to act now, using cities as catalysts to create more sustainable, resilient, and just societies. Today, over 50 percent of the world's population lives in cities, a figure expected to rise to over 68 percent by 20503. While more than 60 percent of the area projected to be urban in 2050 has yet to be built4, cities should plan their growth sustainably and in a manner that reduces vulnerability and risk. Moreover, city planning, and management should be science-based. Investment in research to address urban sustainability and resilience should consider knowledge needs identified by cities themselves, such as in the Findings from Innovate4Cities 2021 and Update to the Global Research and Action Agenda (GRAA), and the Global Covenant of Mayor (GCoM)'s Innovate4Cities Initiative and the City Research and Innovation Agenda (CRIA).

The current rate of city expansion, lack of planning, land management, and housing strategies in the global south (especially in LDCs and SIDS) pushes the most vulnerable into informal areas.

Informal settlers often reside on sites unattractive for development due to susceptibility to climate hazards and disaster risks while penetrating the periphery of ecological assets that serve as natural carbon sinks. At the same time, nature has many often-unaccounted-for benefits to offer informal areas. Nature-based solutions (NBS) and Ecosystem-based Adaptation (EbA), especially when in partnership with the most vulnerable communities, can lower pressure points through reduced heat island effects, improved flood retention, and stabilized erosion-prone land, while stimulating socio-economic and, particularly, food security. This brings the triple dividend of mitigating greenhouse gas emissions, protecting ecological assets and biodiversity, and effectively adapting vulnerable urban communities and the built environment to climate change.

Resilient Settlements for the Urban Poor (RISE UP), one of UN-Habitat's flagship programmes, aims at integrating urban vulnerability and climate change adaptation issues into city-wide and national frameworks, mobilizing, and coordinating large infrastructure investments in resilience and capacity development. Under RISE UP's umbrella and funded by the Swedish International Development Cooperation Agency (Sida), this strategy paper draws from existing research and practical project experience applying NBS for adaptation and building climate resilience in informal areas to understand the potential and challenges for upscaling implementation.

1 IPCC (2022) "Chapter 8: Poverty, Livelihoods and Sustainable Development," in Climate change 2022: Impacts, Adaptation and Vulnerability. IPCC. Available at: ***https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_Chapter08.pdf***

2 UN-Habitat (2020). World Cities Report: the Value of Sustainable Urbanization. UN-Habitat. Available at: ***https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf***

3 UN DESA (2018). 2018 Revision of the World Urbanization Prospects. Available at: ***https://population.un.org/wup/***

4 UNEP & IRP (2013). City-Level Decoupling: Urban Resource Flows and the Governance of Infrastructure Transitions. Available at: ***https://wedocs.unep.org/handle/20.500.11822/8488***

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CHAPTER
01

Introduction: Nature-based solutions, informality, and climate resilience

1.1 Scale of the challenges

The world is warming at an unprecedented pace and human-induced climate change has already caused widespread adverse impacts on people and nature (IPCC, 2022e). There are already observed increases in frequency and intensity of climate and weather extremes in every inhabited region of the world, including heat waves, heavy precipitation events that cause flooding, drought and fire and this is expected to intensify (IPCC, 2022e). Progress on the Sustainable Development Goals has been inhibited and the most vulnerable people are disproportionately affected (IPCC, 2022e). This is only the beginning as global temperatures will continue to rise until at least the middle of the 21st century in all currently possible emission scenarios. If deep emission cuts do not occur, the temperature will rise at least 2.1°C to 3.5°C or even up to 5.7°C by the end of the century (IPCC, 2021).

Over 68% of the world's population is predicted to live in cities by 2050 (UN DESA, 2018) and 95% of this growth is centered in the developing world (UNFCCC, 2020). As a result, informality, whether in the form of informal settlements or the informal economy, is part of this growing urban future. Almost a billion people living in informal settlements in the Global South do not have access to water and sanitation (IPCC, 2022d). Rapid urbanization also has impacts on human and natural systems which potentially undermine the adaptive capacity of cities (Roberts, 2022).

Rapid urbanization contributes to, but is not the only process that has resulted in, 70% of the land area of the planet being transformed from its natural state with widespread environmental degradation which affects an estimated 20-40% of the total land area (UNCCD, 2022). Some critical ecosystems are in even more dire straits with 85% of wetlands degraded and approximately half of live coral reef cover lost, which is being intensified by climate change (IPBES, 2019). This, of course, takes a toll on the biodiversity of these habitats with an estimated one million species facing extinction, and impacts all people - whether urban or rural dwellers - for which nature is essential for their existence and quality of life (IPBES, 2019). Cities are impacted by these global environmental crises with effects on quality of life, provision of services and infrastructure from global environmental change in cities. They influence these urban activities and contribute to environmental degradation through energy and material use (UN-Habitat, 2021).

Despite the scale of these crises, there is a massive implementation gap in tackling climate change in cities (GCoM and UN-Habitat, 2022). Although more than 170 countries and many cities are incorporating adaptation strategies into their plans and policies, there are significant gaps between the adaptation action implemented, what has been planned and what is needed on the ground for the most vulnerable communities. Unfortunately, the gaps are the largest amongst low-income populations. The lack of action to address climate change and the unequal capacity to adapt amongst countries put those vulnerable communities – that depend directly on natural systems to meet their basic needs – at high risk. Additionally, financial resources are insufficient, particularly in the Global South (Roberts, 2022). Of all climate finance, 90% goes to climate mitigation – and the majority of it has been invested in the Global North (COP26, 2021). Between 2010 and 2014, cities received less than 5% of global adaptation finance (Global Commission on Adaptation, 2019). The majority of climate adaptation funds for cities are channeled through national governments. The total amount directed to the subnational level remains unclear and the amount going to building resilience in informal settlements and markets is unknown but is likely minimal and surely not sufficient to match the need.

1.2 The significance of climate resilience and adaptation, nature-based solutions, and informality

Resilience, in a broad sense, is understood as the capacity of a system to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain its essential function, identity and structure (Arctic Council, 2013; IPCC, 2019b). In the climate change context, climate resilience involves the combined efforts of all actors (governments, communities and businesses) to take adaptation and mitigation actions to tackle the impacts of climate change (UNFCCC, 2020). The United Nations Framework Convention on Climate Change (UNFCCC) identifies six important elements to build climate resilience: awareness-raising and advocacy, climate risk assessments and a systems approach, appropriate implementation, resource mobilization, monitoring of progress, and sharing knowledge, experiences and solutions.

Climate adaptation, in this paper defined as the process of adjustment to the actual climate and its effects (IPCC, 2019a), has the potential to go beyond technical strategy based on climate risk projections, and include measures to address intersectional vulnerability and compound risks.

This system-wide, transformational approach to adaptation promotes the need for rapid change at a scale that improves socioeconomic dimensions such as health and livelihoods. As such, climate adaptation can achieve a much wider set of sustainable development targets, and better address the needs, especially, of vulnerable populations that suffer the biggest climate-related harms without appropriate adaptation action. Enhancing adaptive capacities should incorporate strategies to prevent and "deal with the trauma of extreme events" (Roberts, 2022) and to control the spread of diseases that come as a consequence. Providing urban, peri-urban and rural areas with basic services like water, food, shelter, sanitation, drainage, energy access, and means of transport should be included in the process of adjustment to climate change and its impacts, while simultaneously reducing vulnerabilities. Adaptation strategies should also consider the benefits and values of natural ecosystems, which is why nature-based solutions and ecosystem-based adaptation are among the most important climate adaptation strategies known today.

Nature-based solutions (NBS) are actions that promote the relationship between biodiversity and human well-being (Cohen-Shacham et al., 2019), in ways that both reflect cultural and societal values and challenges as well as protect and enhance ecosystems for their continued provision of services (Cohen-Shacham et al., 2016). As climate solutions, NBS include a range of measures to

protect, restore and plant natural ecosystems in order to mitigate greenhouse gas emissions or increase climate resilience. NBS for climate adaptation, often also referred to as ecosystem-based adaptation (EBA) strategies, rely on the use of nature to deal with climate impacts like droughts, heatwaves and floods while supporting the livelihoods of people (Roberts, 2022). As the climate crisis intensifies, NBS are increasingly highlighted as an approach for building resilience in cities with multiple benefits for climate, biodiversity and development. There is a growing experience in the application of NBS in cities across the world, however, more experiences have been shared from countries in the Global North, whereas the majority of growth, as cited above, is concentrated in cities in the Global South.

There are currently two billion people working in the informal economy and one billion residents of informal settlements across the world who are impacted by poverty, social exclusion, climate change, and inadequate urban and health services (Cities Alliance, 2021). Informal economy is understood as basic activities or enterprises that are not subject to formal regulation. Informal settlements are residential areas that fall outside the formal system in terms of land tenure or that do not comply with regulations in relation to planning (lack or inadequate roads to access), land use (need or deficiency of basic services), building materials (use of temporary materials), safety (overcrowding), and health (lack of access to public and/or green space).

In this paper, both the informal economy and informal settlements are included in the definition of informality. People living in informal settlements and/or working in the informal economy are particularly vulnerable to many of the impacts of climate change and are part of the estimated 3.3 to 3.6 billion people in hotspots of high vulnerability to climate change (Roberts, 2022). Given the urban growth and climate change projections for the future, there will be an increase in people living and working in informal areas in parallel with the intensification of the climate crisis. The current rate of city expansion, lack of planning, land management and housing strategies in the Global South – especially in Least Developed Countries (LDCs) and Small Islands Developing States (SIDS) – pushes the most vulnerable urban poor into informal settlements. Informal settlers often reside on sites unattractive or unsuited for development due to susceptibility to climate hazards and disaster risks and environmental degradation while relying on ecological assets. NBS in partnership with the urban poor can thus lower the pressure points for example through reduced heat island effects, improved flood retention, stabilized erosion-prone land or improved food provision, which stimulates socio-economic security, health and wellbeing for the urban poor. This brings the triple dividend of mitigating greenhouse gas emissions, protecting ecological assets and biodiversity, and effectively adapting urban poor communities and the built environment to climate change.

Alzohour triangle in Amman, Jordan (2022)

1.3 Bringing it together: Nature-based solutions for climate resilience in informal areas

Informal settlements and economies are integral parts of many cities across the world. They are critical places for sustainable development and are often at the root of many intersectional vulnerabilities. NBS can offer a promising strategy to protect ecosystems, address societal challenges and deal with the causes and impacts of climate change simultaneously.

The exploration of NBS for climate resilience in informal areas responds in part to the need for a systemic approach to adaptation for climate-resilient development in cities which can enable positive transformations (GCoM and UN-Habitat, 2022). Providing basic services to informal communities increases their adaptive capacity while green spaces in the city contribute to human well-being. Green space generates access to land that in turn improves the quality of life while restoring the ecosystems that help protect life on land and below water (Roberts, 2022).

Advancing NBS for climate resilience in informal areas is particularly interesting to explore given the potential synergies as well as the possibility of breaking new ground.
Following are a few of the potential benefits of bringing these areas together:

- **Innovation:** Although there are a growing number of examples of the application of NBS for climate resilience, this has been limited in informal areas so there is a large potential to test and scale innovative solutions.

- **An integrated approach, breaking out of silos**: There is an opportunity to bring together communities who have worked on NBS and informality separately for integrated solutions that address multiple problems.

- **Increased benefits for nature and people:** By considering these integrated solutions, there is a potential to maximize environmental and social benefits.

- **Address interconnected problems:** NBS - if well implemented with strong community engagement - have the potential to address multiple problems that are simultaneously facing informal settlements and cities, including the lack of urban services, loss of biodiversity and increasing vulnerability to climate change.

Despite encouraging prospects of implementing NBS in informal areas, there are also many unknowns which require more exploration and better understanding. There may also be limitations in how feasible NBS are in some contexts, and how effective they will be in building climate services and improving the wellbeing of informal workers and residents of informal settlements. Finally, there may be instances where tradeoffs instead of synergies need to be considered in terms of which problems to prioritize and how there may be unintended or adverse consequences in some cases.

Mangrove planting in Lovobe, Madagascar (2022)

1.4 Scope and purpose of the paper

This strategy paper aims to draw from both existing research and practical project experience applying NBS for adaptation and building climate resilience in informal areas.

The research section of the paper focuses on the findings summarized in the recently published 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) related to NBS in cities and building resilience in informal areas to identify what can be drawn from the literature. This section also includes an analysis of research gaps that pertain to NBS and informality identified in the Global Research and Action Agenda on Cities and Climate Change (GRAA) from the Cities and Climate Change Science conference in 2018 (IPCC, 2018), the subsequent findings from the Innovate4Cities conference in 2021 that provided an update to the GRAA (GCoM and UN-Habitat, 2022), and the City Research and Innovation Agenda (CRIA) (GCoM 2022).

The section on practice is based on three main sources of practical experiences from: (1) projects on NBS and informality shared at the Innovate4Cities conference and (2) UN-Habitat projects on nature-based solutions in informal settlements and international best practice analysis by Arcadis Shelter Program.

Drawing from both research and practice, the paper then identifies (a) what are some of the interconnected opportunities and challenges of working on NBS to build climate resilience in informal areas, (b) what are some of the special considerations that may need to be taken into account when planning or implementing NBS for adaptation in informal areas and finally (c) what are some of the best practices that can be identified to date. The analysis primarily focuses on informal settlements as this is the topic of the majority of research and practice on informality and climate resilience, however, where possible, linkages are made to the informal economy. There is a glossary in the annex which defines these terms as well as ones related to nature-based solutions and climate resilience.

It is intended that this strategy paper will support strategic discussions and programming and help to catalyze research and action on NBS in informal areas that reduce vulnerability, address climate risk and ultimately contribute to sustainable development for the urban poor and the natural environment.

As a result, the intended audience for this strategy paper includes (1) researchers - to catalyze more research on areas which are unknown about the application of NBS in informal areas or could improve that application informal contexts (2) practitioners and organizations engaged in the implementation of NBS in cities and sustainable urban development in informal areas and (3) policymakers to consider how enabling environments could be improved to catalyze the necessary action and research.

CHAPTER
02

Research areas and remaining gaps on nature-based solutions, urban informality and climate resilience

Research on nature-based solutions (NBS), urban informality and climate resilience has been vital for identifying challenges and developing science-based ambitions and approaches in each of the areas. Research linking climate resilience with either NBS or informality is plentiful and helps to draw out synergies in the approaches as well as practical solutions from many cities and countries. Research linking all three is limited; however, as the following review shows, there are commonalities in terms of interconnected issues and best practices such as vulnerability, equity and justice, and participation and engagement. The existing scientific literature also points to areas where research gaps remain and could help to identify further considerations in the applications of NBS in informal areas.

The following section starts with a review of the recent IPCC 6th Assessment Working Group II: Impacts, Adaptation and Vulnerability report as a basis for key findings linking the three main interconnecting research agendas. The last section on research is derived from the Global Research and Action Agenda on Cities and Climate Change Science (GRAA) and the City Research and Innovation Agenda (CRIA), both of which emerged from the 2018 Cities and Climate Change Science conference and the subsequent findings and updates to that research agenda which emerged from the 2021 Innovate4Cities conference as a basis for the discussion on research gaps on NBS in cities and informality and climate change generally and specific areas of overlap.


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2.1 Nature-based solutions and climate resilience in cities: Key findings in research

NBS are widely recognized as low-regret measures for disaster risk reduction, climate adaptation and resilience in cities and urban settlements. Green and blue infrastructure interventions and natural conservation in and around cities can reduce the impact of and increase resilience to ongoing climate-related changes like sea-level rise and warming temperatures, as well as extreme weather events and shocks like floods, storms, heat waves and droughts. In addition, NBS frequently offer co-benefits for climate mitigation, biodiversity conservation and social development targets including health benefits, livelihood provision, and cultural and recreational benefits (McPhearson *et al.*, 2018; Andersson *et al.*, 2019; Frantzeskaki *et al.*, 2019; IPCC, 2022b). Investing in NBS and ecosystem-based adaptation (EBA) measures can reap net benefits of about 1:4 times the money invested (Global Commission on Adaptation, 2019; Seddon *et al.*, 2020; IPCC, 2022c).

The IPCC has identified six core ways in which nature-based solutions may provide climate adaptive functions for cities and urban settlements (IPCC, 2022d):

1. Urban NBS like green roofs and walls, trees, urban vegetation as well as lakes, ponds and streams can *increase resilience to extreme temperatures and provide urban cooling* through evapotranspiration and shading (Larondelle *et al.*, 2014; Coutts *et al.*, 2016; Bevilacqua *et al.*, 2017; Gunawardena, Wells and Kershaw, 2017; Viguié *et al.*, 2020; IPCC, 2022b).

2. By absorbing air pollutants, affecting ground-level ozone concentrations and indirectly through reduced emissions from cooling and other functions, urban trees, vegetated buildings and green structures have the potential to *improve air quality and reduce health risks* (Tiwary, Reff and Colls, 2008; Janhäll, 2015; McDonald *et al.*, 2016; Matos *et al.*, 2019; IPCC, 2022b).

3. Grass and riparian buffers, forested watersheds, freshwater wetlands, trees and green roofs may help to *manage storm- and wastewater by reducing the volume of runoff and surface flooding*, decreasing contamination through pollutant runoff, and providing stormwater retention (Zhou, 2014; Moore *et al.*, 2016; Rosenzweig and Solecki, 2018; Keeler *et al.*, 2019; Webber *et al.*, 2020; McPhillips *et al.*, 2021; IPCC, 2022b).

4 Coastal ecosystems including coastal forests, coral and oyster reefs, salt marshes and coastal wetlands, seagrass dunes and more, can *provide coastal flood protection* through physical barriers, stormwater absorption and a reduction of wave energy (Zhao *et al.*, 2014; Bridges *et al.*, 2015; Yang, Kerger and Nepf, 2015; Boutwell and Westra, 2016; Group and World Bank Group, 2016; Arkema, Scyphers and Shepard, 2017; Narayan *et al.*, 2017; Dasgupta *et al.*, 2019; Zhu *et al.*, 2020; IPCC, 2022b).

5 Similarly, NBS alongside rivers and floodplains are seen as *measures for riverine flood impact reduction* since they can reduce the volume of floodwater, take away river energy and flood speed, increase water storage and stabilize riverbanks, and minimize the potential for development for impermeable surfaces, thereby creating space for floodwater to expand, improving urban water quality and management, drought protection and overall water supply management (Moore *et al.*, 2016; Pennino, McDonald and Jaffe, 2016; Berland *et al.*, 2017; Gittleman *et al.*, 2017; Keeler *et al.*, 2019; Webber *et al.*, 2020; IPCC, 2022b).

6 Finally, urban agriculture can be understood as a nature-based *food security intervention*, which is especially important among poorer communities, and can simultaneously advance circularity and urban greening (Orsini *et al.*, 2013; IPCC, 2022b). However, this NBS is often practically limited by land availability, especially in areas of rapid land conversion, and in some cases, land use history that makes it unsuited for food production (Satterthwaite, McGranahan and Tacoli, 2010; Vermeiren *et al.*, 2013; Martellozzo *et al.*, 2014; Badami and Ramankutty, 2015; IPCC, 2022b).

2.1.1. Nature-based solutions and urban development: Multiple benefits

The growing interest in NBS in cities and urban areas is also due to their potential delivery of climate mitigation (De la Sota *et al.*, 2019) and development co-benefits, especially for the urban poor and marginalized groups (Poulsen *et al.*, 2015; Cederlöf, 2016; Poulsen, Neff and Winch, 2017; Maughan, Pedersen and Pitt, 2018; Simon-Rojo, 2019; IPCC, 2022b). Such co-benefits include physical and mental health improvements, (Kabisch, van den Bosch and Lafortezza, 2017; Sarkar, Webster and Gallacher, 2018; Engemann *et al.*, 2019; Rojas-Rueda *et al.*, 2019; IPCC, 2022b), local biodiversity habitat provision (Ziter, 2016; Knapp *et al.*, 2019; IPCC, 2022b) and the support of ecosystem-based livelihoods.

The functions that nature provides to urban systems and city dwellers are described as ecosystem services, which are provisioning, supporting, regulating and cultural benefits that people derive from nature. For example, urban ecosystem services include (a) the *provision* of food, raw materials and water; (b) the *regulation* of temperature, decomposition of waste and cleaning of water; (c) *cultural* benefits like spiritual, recreational, knowledge- and art-related functions; and (d) *supporting* services such as underlying natural processes like photosynthesis, nutrient cycling or the water cycle (Gupta and Dube, 2021). By providing, improving or supporting basic services to and for urban communities, NBS can improve the health, food and water security, and livelihoods of the urban poor, and potentially create significant development gains.

However, despite increasing knowledge of the potential benefits of NBS for urban adaptation and pro-poor development, nature-based adaptation and resilience approaches are still under-funded and under-recognized in urban planning and development, particularly in the Global South (Matthews, Lo and Byrne, 2015; Geneletti and Zardo, 2016; Frantzeskaki *et al.*, 2019; IPCC, 2022b). Furthermore, the development of standardized data collection and formatting practices are needed to reduce hindrances to tracking biodiversity benefits and impacts on natural systems (IPCC, 2022d).

2.1.2. Risks of nature-based solutions for urban climate adaptation

Although the potential benefits of NBS as urban adaptation measures outweigh potential risks, it is important to increase awareness and prevention of unintended consequences and mitigate maladaptation risks related to nature-based strategies used in urban areas. The following paragraphs will discuss some of the most common critiques and risks associated with NBS in urban contexts.

Maladaptation and the effect on vulnerabilities

Aside from desired outcomes and planned vulnerability reductions, adaptation interventions can reinforce, redistribute and create new sources of vulnerability, which is referred to as maladaptation. A study on internationally-funded adaptation interventions found that maladaptive outcomes mostly happen when there are:

- insufficient consideration of the vulnerability context,
- a lack of equitable and inclusive participation in adaptive planning and implementation,
- the retrofitting of adaptation into existing development agendas; and
- insufficient critical conceptualization of desired 'adaptation success' (Eriksen et al., 2021).

Some adaptation projects have increased existing vulnerability and inequality, exacerbated tensions and reinforced power dynamics (Eriksen *et al.*, 2021); others have shifted vulnerability from one community to another. For example, flood embankments protecting one community can increase the risk and exposure of floods for other settlements (Ferdous *et al.*, 2020), or lead to the displacement of poor residents (Thomas and Warner, 2019).

Maladaptive interventions can also create new risks or sources of vulnerability. For example, when urban NBS like trees and parks critically reduce water supply for other users, when shallow open water or wetland systems are not appropriately managed to result in an increase in vectors that may spread disease, or when adaptive measures create a false sense of security that disincentivizes further risk-reducing strategies, also called the 'safe development paradox' (Burby, 2006; Magnan *et al.*, 2016).

Finally, adaptation interventions might also rebound, cause harmful lock-in or stop working over time. This can include temporal rebounds, such as hard seawall infrastructure that decreases the choice of future adaptation measures or water management interventions that cause negative impacts on long-term capacity and the environment. Lock-in is a situation where adaptation interventions put communities in potentially negative pathways of change, which has been the case with hard infrastructure adaptation barriers that become indispensable and (too) costly to maintain over time, but also with interventions aimed at building climate-resilience in the agricultural sector and push out small-scale farmers (Wilson, 2014; Juhola *et al.*, 2016; Eriksen *et al.*, 2021).

NBS in urban areas may contribute to gentrification (Haase *et al.*, 2017; Anguelovski *et al.*, 2018; Turkelboom *et al.*, 2018; IPCC, 2022b); increase water demand (Nouri, Borujeni and Hoekstra, 2019; IPCC, 2022b); lead to an uptake of criminal activity, e.g. by providing visual shielding for robberies, assault and illegal trade (Cilliers and Cilliers, 2015; IPCC, 2022b); or increase allergens through pollen emission from certain plant species (Willis and Petrokofsky, 2017; IPCC, 2022b). Comprehensive and holistic planning at the city level helps mitigate those risks.


Vétiver grass plating in Honiara, Solomon Islands

Colonialism, historical inequities and continuous power imbalances

The concept and approaches to climate adaptation were to a large extent developed in western, capitalist and rich economies and thus inherently incorporate values, worldviews, power and political dynamics. When transferring such concepts to new local contexts in other parts of the world, questions of justice, inclusion and historical inequities become central to adaptation planning and implementation (Cameron, 2012; Bassett and Fogelman, 2013; Eriksen, Nightingale and Eakin, 2015; Bordner, Ferguson and Ortolano, 2020).

Similarly, critical climate adaptation scholars highlight the importance of a decolonial lens to climate adaptation, especially when addressing marginalized communities in the Global South. Systems of colonialism, oppression and exploitation have played a major role in creating and maintaining poverty, informality and inequality (Maldonado-Torres, 2017; Bassey, 2019), and adaptation programmes must be careful not to reinforce or replicate such dynamics. The direction and inherent power dynamics in adaptation finance, which typically flows from donors in the Global North to recipients in the Global South, can create new dependencies and spheres of influence, for example by requiring adaptation interventions to align with the donor's agenda and priorities (Cameron, 2012; Bordner, Ferguson and Ortolano, 2020). Transport infrastructure originally set in to facilitate colonial administration and economic activity is another example of colonial heritage that has locked urban development into path-dependent trajectories shaping cities until the present day (Schwanen, 2018).

Colonialism and power imbalances also affect access to resources and patterns of spatial development relevant to NBS. In Bengaluru, India, inequalities in water access are connected to colonial policies that dictated patterns of spatial development that shaped water infrastructure and provision of services (IPCC; 2022b). Further, creating and conserving nature as part of NBS programmes can reinforce or exacerbate existing inequalities given the differentiated access and control over greenspace that exists in many cities (Tozer et al, 2020).

Transferability of adaptation concepts across geographies

When using concepts that originated in one place and applying them in a different location, transferability - the potential applicability across contexts - becomes central (Bos and Brown, 2012; Hintz *et al.*, 2018). Transferability refers to the ability to replicate interventions that in a previous case have led to desired outcomes, to achieve comparable results in a different context (Macário and Viegas, 2006; Hintz *et al.*, 2018). However, many NBS and adaptation solutions are developed in case-specific contexts with unique geographic, infrastructural, political, social and demographic characteristics. For better transferability, researchers stress the need for careful research, context analysis and evaluation of similarities and differences to judge the potential effectiveness and efficiency of NBS in each context (Hintz *et al.*, 2018). For example, green and blue NBS applied in cities can produce a cooling effect for urban heat islands and have been implemented across cities in Europe. However, when bringing such solutions to arid regions or desert cities, the increased vegetation might have a significant impact on already-scarce water resources and negatively affect poor communities through shortages. Similarly, there might also be issues of transferability over time, as an effective adaptation measure, today might not reap the same benefits in five years (Roberts, 2022). Acknowledging that the same adaptation intervention might not always lead to similar and desired outcomes, and incentivizing local knowledge and context-specific analysis can help overcome transferability challenges, especially for informal settlements, and result in more innovative urban climate adaptation.

Impacts of climate change on the effectiveness of nature-based solutions

Finally, NBS and adaptation interventions are themselves vulnerable to climate impacts, and the effectiveness of the services they provide is increasingly under threat at higher warming levels. Despite their large potential benefits, NBS can under no circumstances be understood as an alternative to, or an excuse to delay, a rapid reduction in greenhouse gas emissions (IPCC, 2022a). However, human adaptation actions, including ecosystem protection, restoration, and the use of NBS can increase the climate resilience of biodiversity and ecosystem functioning. Urban planners and adaptation practitioners must mitigate the potential risks of NBS through careful site and species selection, taking into account the complexities of interconnected urban systems.

2.2 Urban informality and climate resilience in cities: Trends and key areas in research

2.2.1 Sustainable development and pro-poor climate resilience gains through nature-based solutions

Aside from well-known benefits for climate mitigation and adaptation, there is growing evidence for a link between nature-based solutions, livelihood provisions and poverty reduction (IPCC, 2022c), however, the long-term synergies and trade-offs are still insufficiently researched. There is more evidence for the potential of NBS to deliver health and development benefits, for example by making water, waste and sanitation systems more resilient to climate impact and improving their service provision to poor areas. Furthermore, many NBS involve greening cities, which have positive outcomes for reducing heat, air pollution and other health risks for residents (IPCC, 2022b).

NBS can also play an important role in providing and supporting livelihoods for poor communities, particularly for groups that depend upon natural capital for their income (Angelsen *et al.*, 2014; IPCC, 2022c). For example, mangroves offer a wide range of services including protection from sea-level rise and storm surges and carbon sequestration, but they also provide services like fish, crabs, timber and fuelwood that, if harvested in regenerative ways, offer sustainable livelihood opportunities to poor communities. Additionally, mangroves support cultural services such as education, recreation and spiritual value to local communities (Quinn *et al.*, 2017; IPCC, 2022c).

Furthermore, there is growing evidence that NBS can counteract some of the health impacts associated with urban living by both promoting healthy lifestyles and decreasing risk factors. Particularly, access to green spaces in urban areas can bring down stress levels and improve children's cognitive and emotional development (Kabisch, van den Bosch and Lafortezza, 2017). When taken in conjunction with the reduction of repetitive stresses due to climate change impacts, the mental health benefits of NBS in urban areas is an area that deserves further research.

2.2.2 Compound vulnerabilities and climate-related challenges of the urban poor

Driven by demographic change, rapid urbanization, social and economic pressures as well as policy failures, vulnerability to climate change is growing in urban areas (IPCC, 2022d). As a consequence, increasing numbers of people living in towns and cities are exposed to heat extremes, flooding, as well as water, food or energy insecurity. Within cities, the different capacities of neighborhoods and individuals to respond to such shocks and stresses with vulnerability-reducing strategies lead to an adaptation gap between the urban rich and the urban poor. Climate change increases the likelihood and frequency of such events, which combined with the described vulnerability translates to an increase in the number of urban habitats and assets at risk from climate change, with the most socially and economically marginalized most affected (IPCC, 2022d).

Vulnerability for the poorest urban settlers is compounded by multiple forms of marginalization and exclusion, including the lack of secure tenure, insufficient and unstable access to basic services, and limited capacity to cope (IPCC, 2022b). Unplanned, inefficient and poorly located urbanization is a major factor in the expansion of cities to areas with increased climate risks like flooding or lands with inadequate water supply for the needs of growing settlements (Tellman *et al.*, 2021; IPCC, 2022b), however often these areas of growing climate risks are the only areas affordable and available for the poorest urban settlers. Research also shows that climate impacts are disproportionately felt in economically and socially marginalized urban communities and that vulnerabilities are increased by other drivers of inequality - including gender, class, age, ethnic origin, sexuality and nonconforming gender orientation (IPCC, 2022b).

Informality is one pathway through which the process of urbanization widens the adaptation gap and increases climate exposure and vulnerability for low-income urban residents (Dobson, 2017; Dodman *et al.*, 2017; IPCC, 2022b). Informality plays a defining role in cities and settlements of the Global South (UN-Habitat, 2016; Banks, Lombard and Mitlin, 2020; Myers, 2021; IPCC, 2022b) and has received growing attention in urban research (Prieur-Richard *et al.*, 2019; IPCC, 2022b). Informal settlements are often located in the most risk-prone areas of the city and can be affected by compound hazards (Dawson *et al.*, 2018; IPCC, 2022b). However, the climate vulnerability faced by residents of informal settlements is

further increased by their limited adaptive capacity, low-quality housing and lacking or insufficient risk-reducing infrastructure (Satterthwaite, McGranahan and Tacoli, 2010; Melore and Nel, 2020; Patel *et al.*, 2021; Twinomuhangi *et al.*, 2021; IPCC, 2022b). As the IPCC writes, "the greatest gains in wellbeing in urban areas can be achieved by prioritizing investment to reduce climate risk for low-income and marginalized residents and targeting informal settlements" (IPCC, 2022b).

As informal communities often lie on the boundary between urbanized and naturalized areas, it is important to recognize the values that such natural systems inherently provide and the adverse socioeconomic effects that can result from the loss of the associated ecosystem services if these systems are not protected. For example, recent studies have correlated deforestation with increases in malaria cases in Brazil, Peru and Indonesia (Vittor *et al.*, 2009; Olson *et al.*, 2010; Garg, 2014). Often linked to climate-risk protection, the provision of basic services as well as livelihood support, natural ecosystems can have particular value for people employed in the informal sector and living in informal settlements. More targeted action towards informal settlements, including but not limited to NBS, can significantly increase impact and socio-economic resilience.

2.2.3 Climate adaptation strategies in urban informal settlements

There are multiple strategies for climate resilience and adaptation interventions in urban informal settlements or for the urban poor. A number of strategies have proven particularly promising to tackle both social and environmental challenges:

1. Strategies mainly aiming at improving the adaptive capacity of residents include *community-based adaptation (CBA)* (Soltesova *et al.*, 2014; Dobson, Nyamweru and Dodman, 2015; IPCC, 2022b) and the *strengthening of financial and social infrastructure* (Haque, Dodman and Hossain, 2014; Ziervogel, Cowen and Ziniades, 2016; IPCC, 2022b).

2. *Climate-resilient development (CRD)* brings together physical, nature-based and social policy interventions in order to provide long-term benefits that prevent unintended outcomes (IPCC, 2022b).

Aside from climate risk reduction, these strategies are sensitive to intersectional vulnerabilities within low-income and minority groups, including women, children, migrants, refugees, internally displaced peoples, and racial/ethnic minority groups, among others. There is a large academic consensus that for leaving no one behind in a warming world, these factors need to be acknowledged, addressed and prioritized. The IPCC notes that adaptation programmes in cities like Quito, Lima, Manizales and Surat are now starting to include informal settlers, disadvantaged youth and other vulnerable groups in adaptation planning, need definition and fair adaptive resource distribution (Hardoy and Velásquez Barrero, 2014; Chu, Anguelovski and Carmin, 2016; Sara, Pfeffer and Baud, 2017; IPCC, 2022b). These processes help mitigate the risk of maladaptation and lead to more inclusive and fair adaptation (Satterthwaite, McGranahan and Tacoli, 2010; Soanes *et al.*, 2021).

Adaptation interventions that include the use of *infrastructure* – including social, ecological, physical and digital – can help to build resilience to climate change (Stewart and Deng, 2014; Baró *et al.*, 2021; IPCC, 2022b), and NBS, when integrated with traditionally defined infrastructure, can increase the success of intended outcomes. However if not applied carefully, these solutions can also contribute to increasing inequality in cities and settlements (Anguelovski *et al.*, 2016; Chu, Anguelovski and Carmin, 2016; Romero-Lankao and Gnatz, 2019; IPCC, 2022b), for example through prioritized upgrading of rich neighborhoods, by focusing on value-adding construction or the protection of existing high-value assets (Long and Rice, 2019; IPCC, 2022b), and by shifting risk to lower-income communities. Structural and systemic forms of marginalization need to be surfaced in order to create innovative, just and equitable climate adaptation responses (Parnell, 2016; Henrique and Tschakert, 2019; Porter *et al.*, 2020; IPCC, 2022b).

2.2.4 A way forward for pro-poor nature-based solutions

Environmental degradation and global warming can undermine climate adaptation and negatively affect already marginalized, resource-dependent groups (IPCC, 2022c). NBS offer the potential to simultaneously protect biodiversity, address development goals, and build climate resilience. However, adaptation measures must be carefully planned and implemented to prevent maladaptive or unintended outcomes, and benefit those most in need. Adaptation interventions are most effective if planned and conducted jointly with national governments, research institutions, and the private and third sectors, taking local needs, knowledge and contexts into account. Climate action should not be considered as an additional or side action to other activities, but rather be mainstreamed into existing policies and development frameworks, for example by using the New Urban Agenda and the UN Sustainable Development Goals (IPCC, 2022b).

Furthermore, the collection of robust and defensible data and transparency in how the data is used in the decision-making process, as recommended in the Natural Capital Protocol (*Natural Capital Protocol*, 2016), can provide value in creating acceptance of NBS approaches when integrated into a stakeholder engagement process. Such an approach supports The City We Need 3.0 Principles 3 (Low carbon climate change) and 7 (Public participation and Democratic Governance) by ensuring technically appropriate approaches to develop NBS solutions and by evaluating the challenges and benefits of proposed approaches through a participatory process.

Consequently, adaptation finance must target the poor and marginalized, as well as the local governance level, to overcome the adaptation gap and achieve climate-compatible development (IPCC, 2022c).

Public park in Morondava, Madagascar (2022)

2.3 Nature-based solutions and informality in cities: Research gaps from the Global Research and Action Agenda for Cities and Climate Change Science and the Innovate4Cities update

At the 43rd Session of the IPCC in Nairobi, the South African government presented a proposal for a Special Report on Climate Change and Cities for the Sixth Assessment cycle, it was subsequently decided that this Special Report would be undertaken in the 7th Assessment cycle. However, at the 44th Session of the IPCC in Bangkok, a proposal for a co-sponsored international conference on the topic was approved. The 2018 Cities and Climate Change Science conference was held in Edmonton bringing together urban policymakers, urban practitioners, researchers and other societal actors to focus on research, practice and policy needed for addressing human-induced climate change as part of sustainable urban transformations. The primary output of this conference was the Global Research and Action Agenda on Cities and Climate Change Science (GRAA) (World Climate Research Programme, 2019), which identified four cross-cutting areas and six topical areas where research and knowledge were needed and was recognized by the IPCC.

Building on this legacy, the Innovate4Cities conference was held in 2021 and focused on the nexus between science, practice and innovation vital to realizing ambitious climate change action in cities across the globe. It also had a strong focus on local and regional priorities and voices and actions from the global to the local level. The implementation gap between what is being done and what needs to be done to address climate change in cities was strongly emphasized throughout the conference. Innovate4Cities 2021 was also an important stocktaking of progress in the knowledge exchange, and the production of evidence-based reports and peer-reviewed publications on cities and climate change which has occurred since the Cities and Climate Change Science conference and could act as supporting information in the AR7 Special Report on Climate Change and Cities.

Fig 1. Innovate4Cities figure expanded. Global Research and Action Agenda on Cities and Climate Change Science illustrating topical areas (middle ring) where research is needed, as well as cross cutting (inner ring) areas for action and delivery approaches (outer ring)

The main outcome documents from Innovate4Cities were the *Findings from Innovate4Cities 2021 and Update to the Global Research and Action Agenda* (GRAA) and the updated City Research and Innovation Agenda (CRIA) (GCoM 2022). The GRAA includes new research gaps for each of the six topical areas previously covered, complemented by a new section on History and Cultural Heritage as well as seven cross-cutting areas (three of which were added before the conference) (GCoM and UN-Habitat, 2022). The updated CRIA includes revised policy, technology, information, data and social interaction priorities for or from city research, based on the updated GRAA. For this paper, two of the topical areas from the GRAA and the update are relevant: (1) Informality and (2) Built and Blue-Green Infrastructure. Several of the cross-cutting areas such as governance, justice and equity, finance, and health also have connections to this paper as well as provide some insight into synergies.

With the research gaps identified for Built and Blue-Green Infrastructure, the main one from Edmonton that is related to nature-based solutions is "Further research is needed to understand the co-benefits of blue/green infrastructure and ecosystem-based adaptation, and how mitigation projects could support decision-making in terms of future infrastructure priorities to address climate change in cities". There is no explicit reference to informality, however, the need to understand co-benefits is relevant given the potential for nature-based solutions in informal areas to contribute to wider sustainable development goals and potentially for the importance of demonstrating the added value and full benefits of utilizing NBS.

Emerging from the update from the Innovate4Cities conference, the research gaps on NBS again did not have an explicit reference to informality, however, several gaps are relevant for the consideration of NBS application in informal areas:

- Research is needed to better understand the benefits and diverse values of urban nature, including health and wellness, and how these vary by socio-economic groups, including Indigenous peoples, within and across cities. Then, building from this understanding further research is needed on how utilizing nature-based solutions can maximize benefits for climate, nature and people as well as improving this understanding can reduce conflicts that may arise around approaches to conservation and restoration.

- Further research to develop a full cost-benefit analysis of the built, blue and green infrastructure solutions to adaptation and mitigation, that include financial and economic implications and social/societal co-benefits, at scale and across different urban environments is needed.

- Research is needed on ways in which communities can be empowered to lead on nature-based solutions for wide-scale public participation and long-term support and sustainability of projects. (GCoM and UN-Habitat, 2022)

The CRIA's interpretation of the GRAA identifies 39 research and innovation gaps, from a city policy and practice perspective. A policy guideline (Oke et al 2022a) specifies the key policy processes the new knowledge from research should contribute, to focus on implementable outputs (see Table 1).

Again, the emphasis on benefits and diverse values, especially recognizing how these may vary by socio-economic groups is relevant for the consideration of NBS for climate resilience in informal areas. This research gap also shows the connections to the cross-cutting issue of Justice and Equity when considering NBS in informal areas whereas the second one listed is linked to financial implications as well as benefits which require attention in the planning and implementation of NBS in informal areas.

Among the research gaps identified for informality in both the GRAA and the update, again there are no explicit references to NBS and the implicit references are more distant. From the GRAA, there is one research gap focused on how there needs to be a better understanding of the vulnerability of people living in informal settlements *(*"Further understanding and research is needed on how inhabitants of both informal settlements and slums are particularly vulnerable to the effects of climate change"*, (*Prieur-Richard *et al.,* 2019; IPCC, 2022b)) and this could extend to how the natural environment compounds or reduces that vulnerability, and contributes to decision-making on NBS.

From the Innovate4Cities conference, there is one research gap focused on community participation which is "Further study is needed on cases of effective community participation and models in informal settlement planning in the context of climate change, especially involving youth and children who make up a large proportion of populations in developing country cities" (GCoM and UN-Habitat, 2022). Although gender does not feature prominently in the GRAA or the update, further understanding of how women and girls could be better integrated into community participation models in adaptation planning for informal settlements and informal economies given their differentiated vulnerability would also be beneficial.

Research in this area would be relevant to empower communities to lead on NBS as highlighted in the final research gap listed above under 'Built and Blue Green Infrastructure' and again points to the synergies with Justice and Equity and the importance of getting the community participation models right for successful implementation of NBS in informal areas.

Table1: Nature-based solutions (NBS), resilience and informality priorities and policy processes identified in the City Research and Innovation Agenda (CRIA) (Modified with permission from Oke et al 2022b)

Legend of priorities	City Research and Innovation Agenda (CRIA) Priorities	Policy Processes M&E – Monitoring and Evaluation A&C- Advocacy and Communications S&O – Strategy and Objectives D&R – Data and Research P&R- Pilot and Replicate					Related to	
		M&E	A&C	S&O	D&R	P&R	NBS or resilience	Informality
Priority 1	Identify a strategic approach to retrofitting city building stock based on building typology to reduce emissions.			x				
Priority 4	Use of social science in engaging a broad group of stakeholders in new initiatives from planning through implementation.				x	x		
Priority 5	Incorporate informal settlements and their residents in urban planning strategies through active consultation and co-creation.			x	x			
Priority 6	Explore connections between water, energy, and materials to develop sustainable solutions in urban areas.	x		x				
Priority 7	Quantify potential and chart implementation pathways for blue/green infrastructure and nature-based solutions to reduce emissions, build adaptive capacity and resilience, provide co-benefits, and address issues of biodiversity.	x		x	x			
Priority 8	Assess planning policies and prioritise actions to help mitigate urban heat island effect.	x		x				
Priority 9	Explore adaptation and resilience in cities through culture and history to better understand their impact on climate action today.				x	x		
Priority 10	Mainstream climate change action planning into city decision making, integrating mitigation and adaptation into comprehensive planning and budgeting processes.			x				
Priority 11	Assess solutions to address the urgency of water-scarcity, pollution, and allocation in cities and their related ecosystems.	x			x			
Priority 13	Further understanding is needed on potential for urban agriculture in terms of climate change mitigation and local food security.				x			

Priority 17	Explore potential for circular economy approach throughout city systems, and how these may differ in developed and developing cities.			x	x			
Priority 24	Increase focus on understanding the finance adaptation gap for cities, including short- and long-term financial needs for nature-based solutions.	x			x			
Priority 25	Governance landscapes (considering formal and informal actors) to support greater generation of municipal revenue and which support groups marginalised due to gender, age, race, ethnicity, religion, Indigenous status and disability.		x	x				
Priority 27	Strategic methods for awarding projects which prioritise sustainability, circular economy, and resilient low-emission roadmaps in urban solutions.			x				
Priority 29	Calculation and communicate of economic and health effects of action vs. inaction.	x	x					
Priority 31	Measures to value a wide range of climate and societal co-benefits of climate solutions.	x			x			
Priority 33	Investigate emerging social innovations in cities that could be exported globally to scale solutions.				x	x		
Priority 34	Explore effective governance frameworks to facilitate city-led research and innovation, including creating space for learning-by-doing and learning-from-failure.				x	x		
Priority 35	Communication of uncertainty and risk of climate hazards for cities.		x					
Priority 36	Understand the mitigation and adaptation potential of city actions, including implications for social equity and justice.	x						
Priority 37	Generate city scale data for development of specific observation, models, and scenarios.				x			
Priority 38	Reduce the gap in climate relevant data on vulnerable communities.				x			
Priority 39	Equitable development and dissemination of knowledge and data inclusive of co-design and co-production through collaborative partnerships across public and private sectors, and civil sectors (including youth, Indigenous populations, residents of informal settlements, and other marginalised individuals).		x	x				

Citation:
GCoM 2022; Oke et al 2022a

CHAPTER
03

Learning from practice on nature-based solutions, informality and climate resilience

3.1 Nature-based solutions and informality practical examples highlighted at Innovate4Cities sessions

The following section draws on lessons learned, challenges and key considerations drawing from sessions focused on nature-based solutions (NBS) and/or informality at the Innovate4Cities conference held in October 2021. Examples are drawn from cases of NBS for climate resilience in informal areas and where relevant, cases of NBS implemented in other contexts are also drawn upon to learn from those practices while recognizing that local contexts may differ in some places.

Community participation, engagement and ownership

There were a few sessions at the Innovate4Cities conference that were explicitly about NBS in informal areas. One session was focused on Sub-Saharan Africa: Nature-based Solutions Approaches to Climate Change Adaptation in Urban Informal Settlements in Sub-Saharan Africa (2021) and featured presentations and discussants from Malawi, Nigeria, and Kenya who highlighted the importance of working with communities to implement NBS in informal settlements. The project from Malawi was a national tree-planting campaign that was initially not successful because thousands of trees were dying annually. By engaging community leaders and utilizing walnut and fruit trees that community members could plant in their yards, there has been an uptake of the initiative. The Nairobi River Rehabilitation Initiative in Kenya faced a similar issue of public acceptance and emphasized the importance of working with communities, for them to understand and experience the potential positive benefits of the actions.

The session Cities that Connect People and Nature: Post Pandemic Green Recovery in Europe (2021) while focused on the European context - also highlighted the importance of stakeholder engagement, especially so that green infrastructure can achieve multiple benefits. Similarly, the session stressed the benefit of early involvement of stakeholders to share ideas and knowledge as well as co-producing and co-creating in the design process.

The session Designing resilient cities: Innovative Co-production and Impact Assessment Approaches for Evidence-based and Inclusive Nature-based Solutions (2021) provided an example of an innovative participatory planning approach that utilized art and imaginative and innovative storytelling in Sarajevo to build community coherence and eco-empathy. The method used data from citizens' memories which helped to close generation gaps and draw on knowledge of ancestors and older generations. It included "walking the city" exercises aimed at clearing mental barriers and picturing environmentally-friendly alternatives.

Incorporating local knowledge

A presentation in one of the potluck sessions highlighted the imbalance of park and tree cover between unplanned and planned residential areas in Delhi and the need to increase green space in unplanned areas to improve the equitable distribution of green space in cities (Potluck session 6G, 2021). This presentation also emphasized the importance of citizen-led NBS as well as integrating local and Indigenous knowledge with expert urban planning knowledge to ensure green spaces are equitably distributed, well maintained and guided by both long-term objectives and diverse measures of success.

Emphasizing multiple benefits, including mitigation

A session on Green Spaces for Healthy Cities discussed green housing models to be implemented in informal settlements. Among the factors highlighted was the need for biophilic design that is affordable, adaptable, and modular that can increase access to ecological resources while also alleviating socio-economic inequalities (Green Spaces for Healthy Cities, 2021). The session Cities that Connect People and Nature: Post Pandemic Green Recovery in Europe (2021) also highlighted addressing multiple agendas or outcomes in green infrastructure development, for example, integrating green spaces into active travel can have multiple benefits for air quality, urban heat island, biodiversity, mental health and wellbeing.

The regional Middle East and North Africa Plenary session (2021) at the conference featured an example of an NBS in the form of a dyke built with compacted earth and dolomite stone to reduce the decline of the marshland ecosystem in Old Damascus City, Syria. Despite initial protests by the local community, eventually, the project was embraced for reconnecting people with nature. Furthermore, the project has mitigation benefits as the plants in the wetlands are absorbing CO2 demonstrating the potential for mitigation and adaptation co-benefits from NBS.

Justice, equity and vulnerability

The session Harnessing Informal Innovation: Lessons from Three Climate Resilient Development Projects in Pacific Island Cities and Towns (2021) emphasized that urban ecosystem services and the legitimacy of urban biodiversity and biomass are increasingly being understood as key aspects of addressing climate change in urban areas while also pointing out that a deeper and more nuanced understanding of the urban areas and climate vulnerabilities in informal settlements is needed. The session explored the need for research methodologies to be decolonized and the value of embedding creative participatory approaches for cities and climate change to overcome justice and inequality, including adaptation decision-making within a justice framework.

Access to services - water

The session on Water as a Resource for Cities (2021) brought up the need for monitoring groundwater. Given that informal use of groundwater is high in many cities and groundwater resources around the world are depleting quickly, diminishing groundwater would impact water access and security for many residents of informal settlements. The quality of groundwater also has an impact on health.

Resilience of informal workers

Another aspect of water is the blue economy, as was covered in the session Building a Sustainable Blue Economy in Cities (2021). The session noted that many informal workers are engaged in the blue economy (e.g. fishing) and therefore discussed potential economic activities and business models that would favor both economic prosperity for vulnerable, informal workers as well as ecosystem preservation and restoration.

Policy and practice/implementation gap

Two sessions, one on NBS (Increasing Resilience through Nature-Based Solutions and Collective Grassroots Action (2021) and the other one focused on innovation for inclusive cities with an emphasis on informal settlements (Innovation for Inclusive, Resilient and Climate-Neutral Cities (2021) highlighted that there is a disconnect between policy and practice. In some cases, there may be the right laws or policies in existence, however those policy measures have not led to sufficient implementation of NBS and/or climate adaptation initiatives. Other issues raised in the sessions include a lack of trust and cooperation between local communities, government and development actors, as well as policies that do not address practical realities on the ground such as jobs and livelihoods.

Policy Processes identified by the CRIA:
23 priorities related to NBS, resilience and /or informality were identified in the CRIA (see Table 1). This new knowledge would contribute to including elements of Monitoring and Evaluation, Advocacy and Communications, Strategy and Objectives, Data and Research, and Pilot and Replicate.

Valuation of nature

Two sessions on NBS tackled issues of the valuation of NBS: Nature-based Solutions for Hydro-meteorological Risk Reduction (2021) and From Nature-based Solutions to the Nature-Based Economy (2021). Although the focus of the sessions was on the European context, questions about the economic, social and environmental valuation of NBS, the quantification of lifetime benefits as well as the sometimes hidden values of nature and how to integrate those into the financial markets were all raised.

The conference brought together many perspectives and sessions on NBS as well as informality from across the globe that can help inform a growing understanding of best practices - such as community participation and integrating local knowledge - as well as areas that require more research - such as valuation of nature - which was highlighted above. There was a strong focus on the importance of local context and knowledge as well as engagement, and strategies were shared on how to use multiple benefits to connect with health, wellbeing and social inequalities. This links with another cross-cutting theme of the conference, Justice and Equity, which was also a key focus in several of the sessions.

3.2 UN-Habitat programmes and projects on nature-based solutions, informality, and climate resilience

Cities, and particularly informal settlements, are home to concentrations of populations that are highly vulnerable to the impact of climate change. Under its Strategic Plan 2020-2023, UN-Habitat is working with partners to help cities and other human settlements to adapt to climate change. The agency continues its efforts to base planning and design on vulnerability analyses to reduce the exposure of populations to climate-related hazards such as flooding and landslides, as well as to address a broader set of natural and human-caused hazards. It also follows pro-poor approaches to building climate resilience in marginalized neighborhoods, slums and informal settlements, while helping cities to integrate such communities into city-wide urban systems. Furthermore, drawing on its local-national mandate and convening power, UN-Habitat promotes multilevel governance approaches so that national governments empower local governments to take climate action through improved frameworks with strong local-national collaboration (UN-Habitat, 2019).

UN-Habitat believes that the spatial dimension of biodiversity conservation intersects with the location of informal settlements. The following case studies from UN-Habitat's portfolio include projects where nature-based solutions and other adaptation measures were the main implemented solution in informal settlements. The adaptation approaches used in these projects involve agriculture, ecosystem restoration and rehabilitation, water, and urban strategies. These projects are community-based and although they do not start essentially from a bottom-up approach, the community is heavily involved in the design, implementation, and maintenance of the adaptation strategies.

Community-based adaptation, community participation and engagement

The project Enhancing urban resilience to climate change impacts and natural disasters (2016) is being implemented in Honiara, Solomon Islands. The city struggles to cope with rapid urbanization and the growth of informal settlements – including the lack of basic services, issues with land tenure and a fragile governance structure – while climate change will further amplify many of the resulting stresses in the future. The project aims to implement adaptation measures with a focus on capacity building to strengthen the climate resilience of the communities. The adaptation strategies implemented

Table 2. UN-Habitat programmes with a focus on climate resilience and vulnerable communities

Cities and Climate Change Initiative (CCCI)	CCCI supports cities in responding to the negative impact of climate change and putting in place appropriate mitigation measures.
City Resilience Global Programme	Raising awareness, sharing knowledge, and engaging in technical cooperation with cities are the major work areas of the City Resilience Global Programme that touches all areas of city planning, management, and functionality.
Disaster Risk Management, Sustainability and Urban Resilience (DiMSUR)	DiMSUR is the sub-regional Technical Center for Disaster Risk Management, Sustainability and Urban Resilience which focuses on innovation and technical assistance, risk reduction and climate change adaptation, gathering African states, academia, people, and NGOs, and targeting African urban resilience and self-governing.
Participatory Slum Upgrading Programme (PSUP)	PSUP addresses the living conditions of millions of slum dwellers worldwide, focusing on the challenges in slums and informal settlements and working in partnership with the communities.
Flagship 3 Resilient Settlements for the Urban Poor (RISE UP)	RISE UP leverages large-scale investment in climate adaptation and urban resilience in urban vulnerability hotspots globally.

consist of catchment management, reforestation, land-use controls, protection of wetlands and soil conservation, flood management through climate-resilient public space (e.g. using floodplains as sports areas), bush gardens, and tree planting to increase shading in community spaces and walkways combating heat stress (Lucy, J. 2022). During implementation, there was a need for a "formal governance structure and extensive support to set up community committees that can guide project implementation transparently and inclusively." Climate-resilient solutions are context-specific to Honiara and difficult to contextualize for future programmes, however, resilience solutions that are applicable at a larger scale are being identified.

Lao People's Democratic Republic is highly vulnerable to climate change due to its reliance on natural resources and its lack of capacity to adapt. The country is being affected by intensifying weather extremes – both drier and rainier seasons. The project Enhancing the climate and disaster resilience of the most vulnerable rural and emerging human settlements has the aim to provide access to basic services in areas vulnerable to storms, floods, droughts, landslides and disease outbreaks (Adaptation Fund Laos, 2021). The adaptation strategies that were implemented include forest rehabilitation, watershed management, small-scale community-based water infrastructure, a dam to preserve water for usage during the dry season, gravity feed systems, irrigation systems and rainwater harvesting with a roof or underground catchments, and small-scale community-based waste-water treatment systems to reuse the treated water in agricultural production. In cases where hybrid infrastructure needs maintenance, "community capacity is essential to guarantee the continued functionality of the infrastructure".

Co-designing solutions

Though Mongolia has not been as affected as other countries by extreme weather events, mean temperatures continue on the rise. One of the impacts in the most vulnerable areas is flooding. The project Flood Resilience in Ulaanbaatar Ger-Areas (FRUGA) Mongolia - Climate Change Adaptation through community-driven small-scale protective and basic services interventions aims to improve the climate resilience to flooding of the seven most vulnerable settlements in Ulaanbaatar City (2018). The adaptation measures implemented in these "temporary" settlements include the reduction of flood risk through resilient urban development and land use management, recycling and treatment of used water, and implementation of comprehensive flood prevention measures such as a flood retention wall, drainage channels, and suitable latrines (for rocky or muddy underground) (Flood Resilience Inception Report, 2019). The involvement of the communities was essential in the design of the adaptation measures – bringing in their life experiences to address the climate impacts on their daily lives so that they support the implementation with a sense of commitment and ownership.

Urban garden training in Honiara, the Solomon Islands (2022)

Integrating community-level governance models

Fiji is highly affected by frequent cyclones together with extreme rainfall, flooding, droughts and sea-level rise. Its geography has caused cities to develop in coastal areas – where they are especially sensitive to some of these climate impacts. Moreover, urban development has led to mangrove deforestation and coral reef extraction. The project Increasing the resilience of informal urban settlements in Fiji that are highly vulnerable to climate change and disaster risks (2016) focuses on communities established near riverbanks and coastal areas. The adaptation strategies include flood control through the construction and improvement of on-site drainage to improve runoff and reduce impacts on access ways, flood resilient sanitation to reduce effluent overspill in times of flood and health impacts, the construction of flood and cyclone resilient housing (e.g. stilted safe rooms) away from foreshore areas, riverbanks and floodplains, an upgrade of water supply sources and diversification of storage types, and hydroponic urban farming (Fiji Resilient Informal Settlements, 2020) During implementation, major efforts were needed to maintain the interaction and strengthen the communities' ownership of infrastructure. In a similar way to Honiara, a formal governance structure was needed for implementation as well as situational solutions for every settlement.

Box 1: Implementation of tree planting in Malawi

76% of the residents of Lilongwe are living in informal settlements, which are situated in poorly drained and flood-prone areas. Heavy seasonal rains have led to massive flooding and human activity such as deforestation, riverbank erosion, development of gullies, indiscriminate disposal of waste along the riverbanks and drainage systems have contributed to the frequent occurrence of flash flooding. UN-Habitat, therefore, is supporting the communities surrounding the two rivers of Lingadzi and Mchesi with nature-based risk reduction measures that were proposed by the communities. The projects in Malawi and Morondova are part of the RISE UP programme, implemented in 2022 under Swedish International Development Cooperation Agency (SIDA) funding.

The project considered community agro-forestry along the rivers with fruit trees, bananas, bamboo and vetiver grass to protect the area from floods. However, this led to a problem of theft of seedlings as the members of the community saw the benefit of food production from the fruit trees, and wanted to plant them in their gardens. After this behavior was noticed, the following strategies were adopted by the same community. First, only ornamental tree seedlings like bamboo and vetiver were planted along the rivers. Secondly, the fruit tree seedlings were distributed to the households and encouraged to plant them in their gardens.

This, however, solved an initial problem of trees that had been planted along the river but with a low success of survival. The communities concluded that this was due to inadequate planting methods but also due to limited care of the trees possibly caused by the lack of a sense of ownership, as described in other projects before. The strategy of planting the tree seedlings on the community members' land might guarantee the care of the trees for a longer period.

An important note on the selection of the tree species is that the planting of drought-resistant species was prioritized such as giant bamboos, bananas and vetiver grass. This decision was taken as the project started at the end of the rainy season in Lilongwe and the communities concluded that it would be difficult to survive for other species.

In summary, experience shows that there is a need for projects promoting NBS to be context specific. However, through synergies with other similar projects, there can be opportunities to share and scale up these solutions. For the implementation of NBS, time delays could arise from seasonality and weather conditions which could result in the need to strengthen resources and capacity. In terms of governance, engagement and capacity building of communities are essential to guarantee the continuous functionality of the infrastructure. Finally, the general documentation of the project, including lessons learned, is a long process limiting access to the information.

Specific to NBS implemented in informal settlements, projects commonly have a need for basic urban services like water, sanitation, and waste disposal. These needs are not easily integrated with adaptation strategies or NBS. There is a need to link access to service issues to adaptation strategies. The lack of integration from these areas could, for example, cause a challenge when deciding which to implement first, whether urban basic services or NBS, when resources or time are limited.

Box 2: Mangrove restoration activities in Morondava

Morondava is surrounded by water bodies and exposed to tropical cyclones. The city is highly prone to flooding and suffers from poor drainage and weak solid waste management systems. Morondava has an estimated population of 60,000 inhabitants and is urbanizing rapidly – with a relatively young population. Approximately 45% of its neighborhoods are considered informal and 25% of the inhabitants live below the national poverty line. UN-Habitat is collaborating with local authorities and organizations to implement – through a community-based approach – long-term nature-based solutions that provide flood protection.

The project's first activity involved mangrove restoration. The sites to be restored were identified using United States Agency for International Development (USAID) Mikajy and World Wildlife Fund (WWF) Morondava maps. This allowed for quick identification of the area without preliminary studies and field visits – as restoration had to happen before the end of the rainy season in April. The mobilization of the young population was also key for the mangrove restoration. The increase in volunteers reduced the time of implementation. Their involvement and awareness – and the engagement of the community in general – also provide them with a sense of ownership that prompts for the caring and maintenance of the restored areas.

Other activities to be undertaken include the removal of invasive species and desilting channels to increase the water-storage capacity of wetlands and converting flood-prone areas into a city park with green walls and sanitary units with green roofs.

3.3 Global examples of nature-based solutions and climate resilience in cities

There are a wider set of experiences where NBS have been implemented in cities to build climate resilience by municipalities and private-sector companies. This rich history of implementation provides further lessons learned that can be drawn upon and translated to informal settlements to take advantage of significant efforts in crafting successful NBS programmes. However, considerations regarding challenges in directly transferring project approaches must be evaluated to select methods that are appropriate to the local context especially socially, financially and technically. The following projects were selected to provide a different perspective in which municipalities and the private sector were leading on NBS. There are of course further examples that can be drawn from, including several useful compendiums, such as the guidance developed by the US Environmental Protection Agency titled, "Building Community Resilience with Nature-Based Solutions" to help share best practices for NBS with communities throughout the United States (FEMA, 2021). This section provides an initial discussion of lessons learned and potential transferability from urban NBS projects implemented in other settings for informal areas.

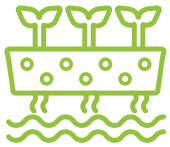
Nature-based Solutions at scale in and around informal settlements

Planning and designing nature-based solutions at different scales can lead to a complementary approach. Interventions can take place at the basin, landscape, community, street, and plot of land scales. The prioritization of increasing green areas and adopting nature-based solutions in urban areas is not an isolated issue of environmentalism but is related to social, economic, and urban improvements in an integrated manner. In addition, a solution can be considered as NBS when the benefits bring resilience and when multifunctionality and biodiversity are behind the solution.

Below are presented some solutions by scale considering their benefits, hazards addressed and limits in application in informal settlements.

Table 3. NBS at basin and landscape scale

Nature-based Solutions	Hazard(s) Addressed	Benefits (Environmental and social)	Limits in application in informal settlements
Sedimentation basin, constructed wetlands, ponds and urban lakes 	Pluvial Flooding Fluvial Flooding Heat	Collect runoff water to allow solids removed from runoff water helping control the environmental degradation Retention of runoff water, protecting from flooding and improving water quality Provide leisure, habitat, biodiversity and aesthetics Reduction of urban heat effect	Requires space for implementation Periodic maintenance is required
Riparian corridor management 	Fluvial Flooding	Provides a buffer to protect from flooding Nutrient-rich soil supports sustainable agriculture practices Provide leisure, habitat, biodiversity and aesthetics	Large areas of land conservation required Periodic maintenance is required
Living shorelines 	Coastal Flooding	Reduces wave action from coastal storms Prevents coastal erosion Supports aquaculture Provide habitat, biodiversity and aesthetics	Requires significant investment Vulnerable to sea level rise
Coastal dunes and wetlands 	Coastal Flooding	Creates a barrier that can buffer waves from coastal storms Supports native vegetation and species	Practices are highly sensitive to human interference

Nature-based Solutions	Hazard(s) Addressed	Benefits (Environmental and social)	Limits in application in informal settlements
Terraces and slopes 	Pluvial Flooding Erosion & Landslides	Increases penetration and filtration of water in the soil Increases retention of runoff water, protecting from flooding Provides better-quality soil for farming Aquifer replenishment Enhancing biodiversity	Not convenient for high-density spaces Not applicable in all soil types and occupancy conditions
Bioretention swales and rain gardens 	Pluvial Flooding Extreme Heat Erosion	Prevents rainfall runoff from causing erosion and flooding downstream Vegetated areas reduce heat island impacts Provides microscale habitat, biodiversity and ecosystem benefits Aquifer replenishment Provide leisure and aesthetics	Can collect trash and fail if not maintained Requires space for implementation Overgrown vegetation can provide habitat for pests or cover for illicit activities
Biofiltration Planter 	Pluvial Flooding Applicable in areas where infiltration of stormwater is not conducive, where existing soil conditions limit infiltration, adjacent to steep slopes (>4%), or in areas with contaminated soils	Provide water and soil quality treatment Peak flow rate reduction Provides microscale habitat and ecosystem benefits Reduction of urban heat effect	Can collect trash and fail if not maintained Requires space for implementation Overgrown vegetation can provide habitat for pests or cover for illicit activities
Infiltration basins/trenches 	Pluvial Flooding	Peak flow rate reduction Flooding management Aquifer replenishment	Requires space for implementation Periodic maintenance is required Overgrown vegetation can provide habitat for pests or cover for illicit activities
Green roofs and living walls 	Pluvial Flooding Extreme Heat	Reduces rainfall runoff from buildings Extends the useful life of building materials by providing protection Reduces energy needed to cool or heat buildings Reduction of urban heat effect Can support localized sustainable agriculture, i.e. rooftop farming Provide leisure, habitat, biodiversity and aesthetics	Requires additional structural support; priority should be on implementation when constructing new buildings Construction materials difficult to obtain Not convenient for high-density spaces

Tree canopy expansion 	Extreme Heat Erosion and Landslides High Winds	Intercepts rainfall and promotes additional infiltration into the soil Shade and evapotranspiration reduce heat at the ground level Root systems reduce erosion and slope stability issues Serves as a windbreak Improved air quality Reduction of urban heat effect Provide biodiversity and aesthetics	Requires unimpacted space below ground to establish a healthy root system Tree falls can be an unintentional hazard if not properly maintained Native tree species should be selected that can withstand droughts and the specific conditions of tree canopies
Rainwater harvesting 	Pluvial Flooding Drought	Prevents rainfall runoff from causing erosion and flooding downstream Collected rainwater can be used for irrigation or other non-potable uses (i.e. for toilet use and laundry) and therefore reduce potable water use and related costs for the local population	Construction materials are difficult to obtain; priority should be on implementation when constructing new buildings Requires active management and additional systems for other uses

Utilizing mapping and ecological valuation for prioritization

The US Army Corps of Engineers (USACE) published an ecological modeling process developed to select cost-effective coastal storm risk management measures in Jamaica Bay adjacent to the boroughs of Brooklyn and Queens in New York City, USA (2018). The goal of the study was to reduce vulnerability to major storms in a way that is sustainable over the long term, both for the natural coastal ecosystem and the local communities. As part of this process, ecosystem services provided by each project alternative were evaluated and each project was scored on a standardized scale for comparison.

The project scoping stage included habitat classification and mapping of all areas adjacent to the proposed projects and mapped estimated boundaries of disturbance associated with the projects. Such mapping helped identify what ecosystems were present that could be restored to provide additional services or that might be impacted by project implementation. Following the mapping process, quantitative data was collected regarding ecological structure, composition and function using standardized rapid assessment methods. The specific scores of each evaluation method were scaled between 0 (fully impacted condition) and 1 (reference condition) to allow for comparison and compilation. Data collected served as a baseline against which decreases or increases in ecosystem services could be estimated based on proposed project designs.

Standardized data collection and evaluation allowed for decision makers to compare how projects would increase or decrease ecosystem services in an unbiased manner. Using an objective approach allowed the USACE to effectively communicate to stakeholders the ecosystem benefits and impacts associated with each project and allowed for an unbiased evaluation of these aspects when selecting between projects of different scale and costs. Furthermore, standardization of the ecosystem service valuation process allowed for the assessment of project benefits and impacts to be temporally scaled, thereby accounting for projects with a differing magnitude of effects across project timelines.

As part of the SIDA/RISE UP project, an urban vulnerability atlas mapping tool is being developed and deployed in Honiara, Solomon Islands; Lilongwe, Malawi; and Morondova, Madagascar. The comprehensive biodiversity and climate vulnerability mapping include development pressures and ecosystem service valuations to help identify areas for prioritization given development pathways, land systems, and watershed/ecosphere management.

Co-designing solutions and collaborative approaches

Following multiple flood disasters that impacted communities throughout New Jersey, the state's Department of Environmental Protection (NJDEP) created the Resilient NJ program (2022) using funding through the U.S. Department of Housing and Urban Development's National Disaster Resilience Competition (NDRC) (2014). The intent of the NDRC was to allocate more than $1 billion USD in federal funding to support disaster recovery that promoted resilience to future risks. NJDEP used a portion of this funding (roughly $5 million USD) to provide technical assistance to four multi-municipal regions along the New Jersey coast to develop and begin to implement long-term resilience plans (Resilient NJ, 2022). Individual municipalities partnered with community-based organizations with direct connection to people who live in affected areas to form regional steering committees to guide the efforts of technical consultants funded by the state through the Resilient NJ program. Local stakeholders were able to provide significant input on the location and type of resiliency measures, emphasizing NBS. This funding provided local municipalities with access to technical resources to identify vulnerabilities, advance planning and pursue funding for capital projects, and establish programs focused on reducing future flood risk. This framework also provided a platform for local municipalities to work together, as well as share a voice to advocate for additional decision makers, to increase regional resilience, leveraging knowledge and resources from more developed, neighboring municipalities to advance initiatives in more environmentally and socially vulnerable communities.

Philadelphia Water Department's (PWD) Green City, Clean Waters program began in 2011 as part of a 25-year plan to reduce overflows from the city's combined sewer system. This program includes engineering solutions such as treatment plant upgrades as well as the implementation of nearly 10,000 greened acres throughout the city (Featherstone, J. *et al.*, 2011). Since its inception, PWD has implemented more than 2,800 green tools, or green stormwater infrastructure, which includes stormwater basins, cisterns, green roofs, stormwater planters and several other different techniques. To implement so many individual green tools distributed throughout the city, with the intention of meeting the larger goal of combined sewer overflows, PWD developed a detailed Green Stormwater Infrastructure Planning & Design Manual and standard details for green tools and associated components (Philadelphia Water Department, 2018 and 2021). With standardized guidance and details in place, PWD can engage a wider range of stakeholders to implement green tools while maintaining confidence that these green tools can provide the desired water quality functions. This has expanded PWD's program participants through increased outreach and incentive programs.

Urban garden in Honiara, the Solomon Islands

Integrated Water Management for flooding and water supply

Addressing climate resilience impacts often requires implementing solutions across boundaries. Such considerations may become even more pronounced when incorporating NBS projects, as these approaches follow ecological boundaries (e.g., watersheds) that may not align with governmental boundaries. As such, regional and local governments have realized the benefit of combining NBS approaches with more traditional infrastructure approaches over a variety of scales. Combining green and gray infrastructure approaches provides flexibility in designing solutions when constraints, such as existing land use and infrastructure, are prevalent. The City of Rotterdam in the Netherlands provides an example of implementing a variety of NBS and traditional infrastructure approaches at varying scales to address urban resilience. With approximately 80% of the city lying below sea level, Rotterdam has an immediate need to address flooding challenges. Therefore, the city has implemented solutions such as the installation of green roofs, redesigning agricultural land for several purposes (e.g., agriculture, ecological habitat, recreation and water storage) and creation of urban parks that serve a dual water storage purpose to address the challenge (Tristan J.,2020; Blauwe Verbinding, n.d.; WEF Stormwater, 2014). This approach has allowed the city to address its immediate flooding issues in a manner that accommodates existing constraints and profits from the benefits of NBS approaches. The multi-use urban water park retains approximately two million liters of stormwater and is coupled with a green-roof NBS approach that retains more than six million liters across the city and provides urban farming, ecological habitat and heat island reduction co-benefits.

A project undertaken through a partnership between Arcadis and UN-Habitat (The Shelter Program) provides an example of regional planning of mixed approaches incorporating NBS that affect urban and periurban areas in Kenya. The Shelter Program team evaluated a variety of low-technology methods to increase water supply to support an Integrated Urban Sustainable Development Plan for Moyale, Kenya. The team assessed the feasibility of NBS methods currently implemented in the regions (e.g., pans/detention basins and sand dams) as well as more traditional gray infrastructure approaches (e.g., check dams and rainwater harvesting tanks). Feasibility was assessed by accounting for factors such as soil infiltration rates, slope, surrounding land use and available land to select appropriate approaches in various geographic areas surrounding Moyale. While the evaluation did not conclude that all water demands could be met through the implementation of the evaluation approaches, it highlighted the need for selecting solutions that included NBS methods and traditional infrastructure methods at a variety of scales. Such an approach would help alleviate some of the water stress experienced by communities in the region and would help bolster local water resources to communities in the regions outlying the city proper.

Over the last decades, the private sector has more formally acknowledged the dependencies of their business operations on natural capital. Impacts to the ecosystems (e.g., loss of wetlands or riparian floodplains to development) that provide these benefits disrupt informal settlements (e.g., flood damage to infrastructure or unreliable water supply) in a similar manner as they do business operations. Therefore, urban planning for informal settlements could benefit from the approaches that the private-sector use to identify early the challenges they face from disruptions to natural systems and the objectives they can achieve through the implementation of NBS approaches. The Microsoft Corporation's approach to water supply provides lessons learned regarding the benefits of identifying these dependencies early and how early integration of NBS approaches facilitates their adoption. The Microsoft Corporation recognizes many of its operations are present in water-stressed regions and has committed to water-positive operations (Smith, B., 2020). As a result of this commitment, Microsoft incorporated NBS designs for its corporate campus in San Jose, USA to achieve net zero water use (Kohnstamm, 2019). The campus incorporates sustainable urban drainage system designs such as rain gardens and 4-acres of living roofs to collect and treat stormwater for use in irrigation before discharge to surrounding watersheds. Integration of natural habitat and biodiversity into the campus design creates a foundation for long-term sustainable operations, improves water quality in surrounding watersheds, increases local biodiversity, and provides mental and physical benefits of access to natural open areas for its employees. Early identification of the natural resource dependencies allowed Microsoft to proactively manage water scarcity challenges, and the incorporation of NBS elements early in the design process allowed the company to realize the co-benefits of these approaches without having to implement more expensive reactive retrofits to existing infrastructure.

While this case study shows the benefits of including NBS aspects early in the design process, the project specifics must be carefully considered to evaluate which aspects are difficult or infeasible to implement in the context of informal settlements. For instance, the project benefited from ownership of a large land parcel on which they had control over project aspects and the project incorporated some technological aspects with high barriers to entry due to

capital and maintenance costs (e.g., onsite water treatment and redistribution). However, the core principle of early identification of the natural resource dependency and early incorporation of NBS elements into the design process were crucial in meeting the project objectives to minimize net water consumption and protect surrounding water quality. These principles should be embraced by specifically considering the needs of informal communities in the urban planning process and engaging community members to identify the natural resource dependencies that they experience. Early engagement of these communities in the urban design process can help minimize maladaptive outcomes that may be associated with NBS projects, such as displacement or failures due to lack of maintenance, by identifying community needs and selecting NBS approaches that meet these needs and account for structural, cultural or fiscal limitations.

Opportunities and risks for the involvement of the private sector in ecosystem-based adaptation

Private sector companies continue to be a major producer of greenhouse gas emissions, land conversion and natural resource extraction, thereby fuelling climate change and creating as well as intensifying biodiversity challenges and vulnerabilities. The ecological and social cost of corporate operations is often not priced into products and services offered, thereby causing negative externalities for society. Public opinion and political leaders increasingly recognize the responsibility of companies for the drivers and impacts of environmental challenges, putting growing pressure on the private sector to operate more sustainably and to contribute actively to climate mitigation and adaptation.

By March 2021, about one-fifth of the world's 1,000 largest corporations had made net zero emission pledges (Oxford University, 2021). However, in-depth analyses of these claims demonstrate that on average, large companies had only committed to 40% emission reductions, often delayed by decades to 2040 or 2050 (Dufrasne, 2022). Furthermore, many companies have been found to use misleading accounting and net zero definitions that only incorporate parts of their emissions and – rather than causing systemic change – seek to maximize their green image at a minimum financial cost and operational impact (Diab, 2022). Nature-based solutions have been one pathway for such greenwashing techniques, for example, to conceal continued greenhouse gas emissions by engaging in offsets and nature-based schemes (Seddon, N., 2022; Ferguson, *et al., 2022*). Additionally, companies that engage in nature-based solutions might – independent of their intention – implement NBS in a way that leads to maladaptive outcomes, for example through top-down approaches that disregard local rights, voices and knowledge, and reinforce power imbalances (Seddon, N. 2022), or shift rather than resolve vulnerabilities. Finally, the misuse of nature-based solutions can even harm biodiversity, for example when planting is prioritized over ecosystem protection and restoration (Seddon, N. 2022)

Using the right safeguards and principles, however, the private sector can become an important vehicle to implement and finance NBS for adaptation. Currently, of the 21% of climate finance that is channeled to adaptation, only 10% reaches the local level – and only half of the local finance is used for nature-based solutions and ecosystem-based adaptation (WUF 11, 2022). The private sector could contribute to closing the financing gap for ecosystem-based adaptation, for example through public-private partnerships.

Private-sector engagement in NBS can contribute to corporate climate and reputational risk management, boost productivity and profitability and lead to a variety of co-benefits for society and nature (WUF11, 2022). Furthermore, companies can indirectly support NBS initiatives by sharing climate risk data and assessments, information and knowledge, and supporting capacity-building for a variety of stakeholders. The private sector is already engaged in climate action, however currently most corporate initiatives focus on mitigation rather than adaptation (Chan, S., *et al.*, 2021). Through mainstreaming NBS for adaptation in their activities, and building more adaptation-related products and services into their portfolio – including those related to natural resource extraction, housing, infrastructure construction and maintenance as well as basic services provision – companies could become key players in financing and implementing ecosystem-based adaptation strategies.

In order to increase effective and impactful private sector involvement in NBS, a multitude of drivers have been identified which can be grouped into the following strategies:

1. **Policies and regulations** to incentivize innovation and engagement of corporations in NBS, including awareness-building campaigns, the integration of the private sector in NDCs, the recognition of nature-based solutions in coming climate agreements like comping COP treaties, and policies that enable the engagement of companies in NBS, e.g. by reducing financial risks (Crick et al., 2018; African Development Bank, 2021; WUF11, 2022; Global Center on Adaptation, 2021)

2. **Financial and economic instruments,** such as insurance schemes to enable adaptation and resilience building, particularly for smaller and medium-sized enterprises. Such instruments can increase confidence and risk acceptance of private actors to enter the NBS space, and enable private capital investment through co-financing or insurance schemes that increase the willingness of corporations to invest and thus the overall finance flowing in the sector. (Crick et al., 2018; African Development Bank, 2021; WUF11, 2022; Global Center on Adaptation, 2021)

3. **Collaboration and capacity building** that focuses on actors with limited resources and enables a growing number of partnerships and coordinated approaches to NBS. This should especially incentivize the participation of small and micro enterprises that play an important role in production and employment, but are frequently less engaged in climate adaptation due to a lack of awareness, capacity and international attention in partnerships that traditionally focus on larger, more known private actors with established ESG plans. (Schaer & Delani Karuppu, 2018; Dougherty-Choux, 2015; Global Center on Adaptation, 2021)

4. **Information and data sharing and provision**, both from the government to companies and horizontally and vertically across the supply chain. Sharing more climate-related knowledge can help companies and other stakeholders reduce uncertainty, and guide planning and decision-making by businesses (Global Center on Adaptation, 2021).

5. **NBS framing and awareness of business opportunities** in NBS can be improved through clear communication that promotes local entrepreneurship and a clear vision of the role corporate actors can play in advancing resilience through NBS in profitable and efficient ways (WUF11, 2022; Global Center on Adaptation, 2021; Hale *et al., 2021*).

Nursery home for vétiver grass and bamboo in Honiara, the Solomon Islands (2022)

CHAPTER
04

Recommendations and discussion topics for further research and action on nature-based solutions, informality and climate resilience

Through the analysis of research and practical examples, three areas emerged for discussion and recommendations for further action on nature-based solutions (NBS), informality and climate resilience: (1) Best Practices (2) Special Considerations for NBS in informal areas (3) Interconnected Challenges and Opportunities.

This section begins with a summary of *Best Practices* that emerge from the literature and a review of practical examples that can contribute to recommendations for further application of NBS in informal areas as well as encourage the collection of more examples to broaden the knowledge and experience base.

This is followed by reflections on *Special Considerations* which are issues that may be particular to the application of NBS for climate resilience in informal areas or may need more research to help unpack and better understand the implications of how these issues may be different or more complex.

The final category is *Interconnected Challenges and Opportunities* - which can help to identify connected problems and solutions that would promote an integrated approach as well as connect to other fields of research and study. In particular, these may be issues that could make the application of NBS more difficult, for example, land tenure issues, or they may be critical for ensuring positive development outcomes, such as access to services. These may be areas for more integral research to ensure projects are planned and implemented well.

4.1 Best practices

There are several areas for best practices that emerge from the practical examples as well as indications from the research. These have been grouped into four main categories: (1) Community Involvement (2) Knowledge and Information (3) Benefits (4) Governance. The majority of best practices are related to community involvement which is critically important, however, there is certainly a need to identify more best practices, ideally in the application of NBS in informal areas but also related to NBS in cities generally and work in informal areas to build sustainability for better outcomes for people, nature and climate resilience that may not be classified as NBS.

Table 4. Best practices

Category	Best Practice	Drawing from research and practice
Community involvement	Community participation and engagement	Both the GRAA Research Gaps and Innovate4Cities CRIA examples highlight the importance of community participation and engagement, including innovative methods such as the storytelling approach utilized in Sarajevo.
	Co-designing solutions with local communities	The UN-Habitat project Flood Resilience in Ulaanbaatar Ger-Areas (FRUGA) Mongolia - Climate Change Adaptation through community-driven small-scale protective and basic services interventions and sessions from Innovate4Cities highlight the importance of co-designing projects and solutions with affected communities. The example from Resilient New Jersey also demonstrates how local stakeholders were involved in regional steering committees to guide decisions on location and type of measures - working closely with municipalities.
	Community-based adaptation (CBA)	CBA comes across as an effective practice from both Section 2.2 drawn from the IPCC WGII report and several of the UN-Habitat projects
	Community ownership and decision-making (governance)	The importance of community ownership in a project was highlighted in the Nairobi River Rehabilitation presentation from Innovate4Cities as well as two UN-Habitat projects: Increasing the resilience of informal urban settlements in Fiji that are highly vulnerable to climate change and disaster risks & Malawi experience as part of RISE UP programme and funded by the Swedish International Development Cooperation Agency (Sida). Community involvement in the conceptual design of NBS projects not only ensures that such projects address concerns of the communities most directly impacted, but also increases acceptance of proposed solutions and long-term benefit to underserved communities (see examples of Resilient by Design and San Francisco Bay Restoration Authority).
	Maintenance	Proper maintenance of NBS projects is critical to ensure long-term function. While such maintenance may be undertaken by governmental entities, fostering a sense of ownership from community members will provide opportunities to more consistently evaluate the need for corrective actions and also an opportunity for citizen-based science to supplement monitoring of project function.

Category	Best Practice	Drawing from research and practice
Knowledge and information	Local and Indigenous knowledge integration	Local and Indigenous knowledge can apply to many aspects including the history of places, the current context and experience of people living and working in informality as well as local knowledge on biodiversity and ecosystems that are important for designing the most appropriate solutions. The presentation on Delhi and tree cover from Innovate4Cities also emphasized the need to bring together different types of knowledge and expertise for urban planning. The integration of social science, physical science, research, experience, local observations, history and culture are all relevant to the application of NBS in informal areas.
	Spatial analysis of risks, biodiversity and socio-economic data	An urban vulnerability atlas, a spatial analysis tool, developed by the University of Pennsylvania as part of this project overlays data on climate risks, biodiversity and socio-economic data in Honiara, Solomon Islands; Lilongwe, Malawi and Morondava, Madagascar - which can support planning for where interventions would be most beneficial. Mapping was also utilized in New York to identify ecosystems present in project areas to assess the potential ecosystem services provided by each project alternative.
Benefits	Emphasis on multiple benefits	It is widely recognized that NBS have the potential to deliver multiple benefits, including mitigation, health and ecosystem services as described in Section 2. However many projects miss the opportunity to emphasize these multiple benefits and doing so could encourage further community buy-in, as the example from Old Damascus from Innovate4Cities demonstrated.
	Climate Resilient Development (CRD) framing	CRD, as explained in Section 2.2 incorporates intersectional vulnerabilities as well as the emphasis on long-term social and environmental benefits. Growing research and understanding of CRD could provide an opportunity to further understand underlying vulnerabilities as well as to highlight multiple development benefits that would be derived from projects.
Governance	Multi-level governance	NBS, climate resilience and informality do not exist in a vacuum but rather are connected to larger landscapes, and geographical and political boundaries, consequently multi-level governance and engaging vertically and horizontally on NBS for climate resilience in informal areas is critical and related to issues of scale and cooperation that have been raised.

Tree planting in Lilongwe, Malawi (2022)

4.2 Special considerations for nature-based solutions in informal areas

With the potential for increased application of NBS to build climate resilience in informal areas, in addition to the best practices cited above, there are also areas highlighted through the review of relevant research and practice that indicate special considerations. These may be areas that could make implementation difficult, that would require a different project design or that would benefit from more nuanced research specific to NBS in informal areas to better understand the issues. The following table describes the key issues as well as why these are considered important, drawing on the previous sections and then includes recommendations for research and/or actions in these areas.

Table 5. Special considerations for nature-based solutions in informal areas

Special considerations for NBS in informal areas	Importance	Recommendations
Risk of maladaptation	The risk of increasing vulnerabilities or unintended negative consequences is an important consideration in informal areas (based on section 2.3 on research; no information on practice found)	Critical assessment of where maladaptation has occurred in informal areas; thorough and critical Environmental and Social Safeguard screening and scoping throughout the project life cycle to identify and mitigate the risk of maladaptation early; Increasing awareness about the risk of maladaptation and mitigation measures
Scale – neighborhood, city, regional, landscape	Much of the work on informality is concentrated on neighborhood or potentially city scale, however, NBS best practices generally involve a larger scale of landscape or regional level. In addition, the majority of the neighborhood and city-level projects with NBS have involved the creation of green spaces	More research into the appropriate scale for implementation for NBS incorporating informal areas would be useful; Better integration of informal areas into larger scale NBS projects at citywide or landscape level to maximize benefits; Better anticipation of spatial expansion trends triggering informal settlement development and adversely impacting adjacent biodiversity
Transferability	Many of the research and practice examples are developed based on cases and experiences in the US and Europe which do not have high rates of informality. In addition, the local ecosystems and biodiversity and urban fabric are different in those cities than in cities in Africa, Asia and Latin America. Transferability between cities in these regions can also be difficult given the different contexts for NBS and the variation of the urban fabric. As a result, while some lessons, tools and experiences may have a high potential for transferability, they may be limited in other cases. Financing and financing mechanisms can be particular obstacles (reflections based on the review of Innovate4Cities sessions and examples in section 3.3)	Develop guidelines and/or critical analysis of tools, best practices and lessons emerging from NBS application in developed countries to better understand transferability to informal contexts; Linked to local and traditional knowledge best practice recommendations; Finance mechanisms for NBS integration and application in the informal context
Valuation of nature – by whom, for what	How nature is valued - both economically and socially - as well as hidden values of nature - and who values nature is relevant to decisions on how NBS are planned, designed and implemented in cities generally, as well as informal areas specifically, especially given historical inequities and exclusions (based on Section 2.1, Section 2.4, Section 3.1)	As suggested by the GRAA, further research on diverse values of urban nature and how these vary by socio-economic groups with a focus on residents of informal settlements and informal workers would be extremely useful in planning and designing NBS for these communities; in terms of practice, improving on consultation processes with local communities in these areas that focus on how they value nature would benefit the project design and implementation

4.3 Interconnected challenges and opportunities

As highlighted in the first section, there are a lot of linkages between NBS, informality and climate resilience and the potential for these synergies to deliver benefits across multiple agendas for development, climate and biodiversity is part of the great appeal of NBS in cities. In addition to the connection between these three concepts, there are also other interconnected issues that the application of NBS for climate resilience in informal areas could either contribute to addressing or may have the potential to exacerbate if application and research do not take into account these connections.

Table 6. Interconnected challenges and opportunities

Interconnected issues	Importance	Recommendations for research and practice
Access to services - including water	Access to services is of critical importance and a priority area to communities living in informal settlements. In addition, a lot of water use is informal as was noted in an Innovate4Cities session, yet many of the projects do not center on service provision including waste collection, sanitation and water resulting in a mismatch of implementation and community priorities (Sections 3.1 and 3.2); The examples from Kenya and Rotterdam (Section 3.3) also demonstrate how an integrated water approach can address multiple objectives	Exploring how NBS projects could be coupled with service delivery that benefits both people and nature while building climate resilience; A better understanding of how informal workers and informal settlement residents utilize ecosystem services - water, food, fuel - would also help to build these linkages (connection to Valuation point above)
Justice and equity	Increasingly climate resilience discussions are recognizing issues related to justice and equity which are linked both to the historical and current situation in informal areas as well as to the distribution of nature and access to natural environment resources (Section 2.2; Section 2.4); Justice and equity is also an issue when considering engagement with the private sector, especially large corporations which have been main drivers of environmental degradation and climate change which are now undertaking NBS activities.	A better understanding of how the planning, design and implementation of NBS in informal areas can contribute to climate and environmental justice as well as increased equity in these areas would have multiple benefits; Safeguards, checks on corporate responsibilities and other mechanisms to ensure that historical power dynamics are not replicated in cases where the private sector are engaged
Health	Many studies have documented the health benefits of NBS, however, there may be some transferability issues (see section above) based on where these studies were undertaken (Section 2.1); Health remains a critical issue for communities of informal workers and informal settlement residents so meaningful contributions of NBS to this would have multiple development benefits. Additional NBS projects must be thoughtfully designed and maintained to reduce the potential for resulting adverse health effects (e.g., the proliferation of vector-borne disease).	More research on the health benefits of NBS in informal areas; Development of NBS projects in informal areas with explicit health benefits

Interconnected issues	Importance	Recommendations for research and practice
Land tenure	Land tenure has historically been and continues to be an issue in informal settlements which can be exacerbated by both climate impacts and measures to protect against climate change causing displacement. The creation of NBS can confront issues of who owns the land and who can authorize this type of development	Ensuring safeguards on land tenure are implemented in NBS projects; Include an analysis of land ownership and land tenure in scoping of NBS projects; NBS programmes must be careful to avoid expelling people from unrecorded land, or negatively affecting them; NBS projects and policies sensitive to land right issues can promote tenure security and enable investment in appropriate and permanent adaptive measures by residents and other actors
Historical inequities	Historical inequities have resulted in imbalanced spatial patterns in cities which resulted in informal settlements being located in particularly vulnerable areas. In many cities in the Global South, colonial powers have locked-in city layouts, transport systems and the distribution of neighborhoods among rich and poor communities, which often prevail until today. In addition, access to the natural environment and distribution of greenspace has also been imbalanced with wealthier neighborhoods generally benefitting from more greenspace and access.	Consider in projects how NBS can help correct historical imbalances; Further research on the distribution of greenspace and access to the natural environment and correlation with the wealth of neighborhoods and risk profiles

The intention of this strategy paper was to bring together research and practical examples on NBS for climate resilience in cities and informal settlements to understand what areas should be explored in the potential expansion of the application of NBS for climate resilience in informal areas. This paper is intended as a starting point to bring together communities working on NBS, informality, urban poverty and sustainable urban development to bridge these communities and encourage further discussion.

Inputs and reflections from partners at the Expert Group Meeting (EGM) held in June 2022 have been incorporated, however the paper has also only begun to unpack many of the intersectional issues on governance, justice and equity, ecosystem functioning and degradation, and biological diversity that affect the design and implementation of NBS which are areas for further exploration and research.

The authors also recognize that the paper focuses more on informal settlements than the informal economy which is also a major part of cities in developing countries and would have a different relationship to the application of NBS.

Finally, while there have been some attempts to identify that there are different communities within informal areas and that vulnerability and marginalization affect groups of people and individuals differently, the authors also recognize that much more research and analysis could be done on gender disaggregated solutions, empowerment of women and girls, and the vulnerability and potential to be agents of change that is different for the elderly, youth and children, indigenous peoples, migrants, and people with disabilities living and working in informal areas.

Appendix

A. Definition of Concepts

Adaptation. In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2019).

Reason for urban focus: "Cities and settlements are crucial both as sites of potential action on climate change, and sites of increased exposure to risk" (IPCC WGII, p. 6-13)

Biodiversity. Or biological diversity — means the diversity of life in all its forms—the diversity of species, of genetic variations within one species, and of ecosystems. The importance of biological diversity to human society is hard to overstate. An estimated 40 percent of the global economy is based on biological products and processes. Poor people, especially those living in areas of low agricultural productivity, depend especially heavily on the genetic diversity of the environment (Convention on Biological Diversity, 2008).

Blue/Green infrastructure. Refers to infrastructure that aims at restoring the naturally oriented water cycle while contributing to amenity by bringing water management and green infrastructure together, while gray infrastructure refers to human-engineered traditional approaches to water management such as pipes and hard surfaces (Kapetas & Fenner, 2020).

Urban green infrastructure. Public and private green spaces, including remnant native vegetation, parks, private gardens, golf courses, street trees, urban farming and engineered options such as green roofs, green walls, biofilters and rain gardens (Norton et al., 2015).

Degradation. Damage to the chemical, biological and/or physical structure of soil (soil degradation) and to the forest itself (forest degradation), as a result of incorrect use or management, which, if not ameliorated, will reduce or destroy the production potential of a forest ecosystem (in perpetuity) (UNTERM, n.d.)

Land degradation. A negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans. [Note: This definition applies to forest and non-forest land. Changes in land condition resulting solely from natural processes (such as volcanic eruptions) are not considered to be land degradation. Reduction of biological productivity or ecological integrity or value to humans can constitute degradation, but any one of these changes need not necessarily be considered degradation (IPCC, 2019).

Developing countries. Low- and middle-income countries in which most people have a lower standard of living with access to fewer goods and services than do most people in high-income countries. There are currently about 125 developing countries with populations over 1 million; in 1997, their total population was more than 4.89 billion. Organizations may use different statistical criteria to classify how 'developed' a country is. There are many different indicators of development that can be used for such classification (World Bank, n.d.; UNTERM, n.d.).

There are a diversity of approaches for categorizing countries on the basis of their level of economic development, and for defining terms such as industrialized, developed, or developing. In the United Nations system, there is no established convention for designating developed and developing countries or areas. The United Nations Statistics Division specifies developed and developing regions based on common practice. In addition, specific countries are designated as Least Developed Countries (LDC), landlocked developing countries, small island developing states, and transition economies. Many countries appear in more than one of these categories (IPCC, 2019). More recent publications at UN-Habitat are using the term "Global South" to refer to developing countries, though there is no official definition provided by the UN.

Ecosystem-based adaptation (EBA). The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. The ecosystem-based adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies (CBD, 2009; IPCC, 2014).

Ecosystem services. Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fiber, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation (IPCC, 2019).

Global South. The use of the term "South" to refer to developing countries collectively has been part of the shorthand of international relations since the 1970s. It rests on the fact that all of the world's industrially developed countries (with the exception of Australia and New Zealand) lie to the north of their developing countries. The term does not imply that all developing countries are similar and can be lumped together in one category. What it does highlight is that although developing countries range across the spectrum in every economic, social and political attribute, they all share a set of vulnerabilities and challenges (United Nations, n.d.)

Hazard. The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2019).

Informal economy. The part of an economy that escapes regulation by government authorities, particularly in the areas of contract and company law, taxation and labor law; hence the basic activities of enterprises are not, or not consistently, subject to formal regulation and oversight (UNTERM, n.d.).

Informal settlement. A term given to settlements or residential areas that by at least one criterion fall outside official rules and regulations. Most informal settlements have poor housing (with the widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads, and basic services is inadequate or lacking. The term slum is often used for informal settlements, although it is misleading as many informal settlements develop into good-quality residential areas, especially where governments support such development (IPCC, 2014).

"The term 'informal settlement' refers to urban settlements or neighborhoods that developed outside the formal system that is meant to record land ownership and tenure and without meeting a range of regulations relating to planning and land use, built structures and health and safety" (IPCC WGII, p. 6-13)

Residential areas where inhabitants are deemed by the authorities to have no legal claim to the land they occupy and the system of occupation ranges from squatting to informal rental housing. In most cases, the housing is insecure and of poor quality and does not comply with current planning and building regulations. Informal settlements are also often situated in the most precarious urban areas where basic services and infrastructure including public or green spaces are limited (UN-Habitat, 2003).

Rehabilitation. In relation to the environment, ecosystems, buildings and other relevant areas, "rehabilitation" is understood as a repair that allows the productivity, use or proper functioning of an object or system to be restored, without necessarily restoring the situation that existed before the damage (UNTERM, n.d.)

Land rehabilitation. Direct or indirect actions undertaken with the aim of reinstating a level of ecosystem functionality, where the goal is the provision of goods and services rather than ecological restoration (McDonald, et al., 2016).

Maladaptation (or Maladaptive actions). Actions that may lead to increased risk of adverse climate-related outcomes, including increased greenhouse gas (GHG) emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence (IPCC, 2019).

Nature-based solutions (NBS). Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al., 2016).

Resilience. The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains the capacity for adaptation, learning and/or transformation (adapted from the Arctic Council, 2013; IPCC, 2019).

Restoration. In the environmental context, restoration involves human interventions to assist the recovery of an ecosystem that has been previously degraded, damaged or destroyed (IPCC, 2019: Annex I).

Land restoration. The process of assisting the recovery of land from a degraded state (IPBES, 2018; McDonald et al. 2015).

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Risk. The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making (see also risk management, adaptation, and mitigation). In the context of climate change responses, risks resulting from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals (see also risk trade-off). Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions (IPCC, 2019).

Soil conservation. The maintenance of soil fertility through controlling erosion, preserving soil organic matter, ensuring favorable soil physical properties, and retaining nutrients (Young, 1989).

Vulnerability. The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2019).

Transferability (of solutions). Transferability refers to the potential of a solution to be applicable to different contexts (Bos and Brown, 2012) with the aim to achieve comparable results with measures that were previously successfully applied (Macário and Viegas, 2006). Transferability offers the opportunity to learn from effective contextual solutions, extract their essential characteristics and analyze them for possibilities of application in different contexts. This requires research to generate the evidence base for judging the effectiveness and efficiency of the chosen solutions. Evaluation needs to capture solution outputs (e.g. created structures, changed behaviors, etc.), appraise their effectiveness by analyzing the outcomes (e.g. to what extent does a solution help to solve a problem), and trace back the processes for generating results (e.g. sequence of action, collaboration, etc.) and the invested inputs (e.g. financial resources, participants' commitment, etc.) (Luederitz et al., 2016). Generating such knowledge would facilitate the analysis of solutions' applicability in different contexts (Hintz et al., 2018).

B. International Agreements pertaining to nature-based solutions, informality and climate resilience

Outlined below are the key relevant international agreements related to NBS, informality and climate resilience.

2030 Agenda for Sustainable Development

The Agenda is a plan advocating the action of all countries for sustainable development for people, the planet and prosperity (UN, 2015). As part of the 2030 Agenda for Sustainable Development, the **Sustainable Development Goals (SDGs)** are a call for action by all countries to promote prosperity while protecting the planet (UN, 2018). Around 65-70 percent of the SDG targets are directly related to cities. Among the 17 SDGs, the following are relevant for this strategy paper:

Goal 1.
End poverty in all its from everywhere.

Goal 2.
End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 3.
Ensure healthy lives and promote well-being for all at all ages.

Goal 6.
Ensure availability and sustainable management of water and sanitation for all.

Goal 9.
Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Goal 10.
Reduced inequality within and among countries.

Goal 11.
Make cities and human settlements inclusive, safe, resilient and sustainable.

Goal 13.
Take urgent action to combat climate change and its impacts.

Goal 14.
Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Goal 15.
Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Goal 17.
Strengthen the means of implementation and revitalize the global partnership for sustainable development.

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Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is dedicated to promoting sustainable development. It recognizes that biological diversity is about more than plants, animals and microorganisms and their ecosystems – it is about people and their need for food security, fresh air, clean water, shelter, and a healthy environment in which to live (2011). The CBD understands biological diversity – or biodiversity – in all its forms and scales, from ecosystems to genetics. The CBD aims to build a nature-positive world, fully recovering its biological diversity by 2050. It also incorporates local government engagement and inclusion in recent biodiversity development for transformative action after the 2020 global biodiversity framework.

New Urban Agenda

The New Urban Agenda (NUA) represents a shared vision for a better and more sustainable future. It contains recommendations that can enable governments across the world to fight inequalities, take transformative climate action and improve the quality of life for all (UN, 2016). The NUA has five main pillars for implementation: national urban policies, urban legislation and regulations, urban planning and design, local economy and municipal finance, and local implementation – being the reinforcing drivers of legislation, planning and finance of relevance to the paper. The commitments related to this document are the following:

- Provide basic services for all citizens
- Ensure that all citizens have access to equal opportunities and face no discrimination
- Strengthen resilience in cities to reduce the risk and the impact of disasters
- Take action to address climate change by reducing their greenhouse gas emissions
- Improve connectivity and support innovative and green initiatives
- Promote safe, accessible and green public spaces

United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) aims to stabilize greenhouse gas concentrations internationally to prevent dangerous anthropogenic interference with the climate system. Under its process and meetings, the **Paris Agreement** is most relevant in its efforts to combat climate change and adapt to its effects. "Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels (UNFCCC, 2015)." Relevant campaigns for climate action include the **Marrakech Partnership** which supports the implementation of the Paris Agreement by enabling collaboration between different stakeholders (UNFCCC, 2021a). The **Race to Zero** campaign promotes "a healthy, resilient, zero-carbon recovery that prevents future threats, creates decent jobs, and unlocks inclusive, sustainable growth (UNFCCC, 2021b)." Its sibling campaign **Race to Resilience** pursues a resilient world by putting people and nature first (UNFCCC, 2021c). Under the UNFCCC process and meetings specifically focused on adaptation, the **Cancun Adaptation Framework** "seeks to reduce vulnerability and build resilience in developing countries" (UNFCCC, 2011).

Sendai Framework for Disaster Risk Reduction 2015-2030

The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) lays out concrete actions for governments to prevent and reduce disaster risks – while sharing the responsibility with other stakeholders (UNDRR, 2015a). Under its seven global targets, the most relevant to the paper are:

- Reduce the number of people affected globally.
- Reduce disaster damage to critical infrastructure and disruption of basic services.
- Increase the number of countries with national and local disaster risk reduction strategies.
- Substantially enhance international cooperation with developing countries.

From its four priorities (UNDRR, 2015b), the following are related to the paper:

- Investing in disaster reduction for resilience
- Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

C. Case Studies

Table 7. UN-Habitat's projects on nature-based solutions, informality, and climate adaptation from RISE UP

Project	Status	Location	Adaptation Strategies
Building climate resilience of urban systems through Ecosystem-based Adaptation (EBA) in the Asia-Pacific region	In Progress	Bhutan, Cambodia, Lao People's Democratic Republic and Myanmar	Urban reforestation Urban agriculture Wetland restoration
Enhancing the climate and disaster resilience of the most vulnerable rural and emerging human settlements	In Progress	Lao People's Democratic Republic	Forest rehabilitation Watershed management Small-scale community-based water infrastructure A dam to preserve water for usage during the dry season Gravity feed systems Irrigation systems Rainwater harvesting with a roof or underground catchments Small-scale community-based waste-water treatment systems to reuse the treated water in agricultural production
Increasing the resilience of informal urban settlements in Fiji that are highly vulnerable to climate change and disaster risks	In Progress	Fiji	Flood control through the construction and improvement of on-site drainage to improve runoff and reduce impacts on access ways Flood resilient sanitation to reduce effluent overspill in times of flood and reduce health impacts Construction of flood (and cyclone) resilient housing (e.g. stilted safe rooms) away from foreshore areas, riverbanks and floodplains Upgrade of water supply sources and diversification of storage types Hydroponic urban farming
Enhancing urban resilience to climate change impacts and natural disasters: Honiara	In Progress	Solomon Islands	Catchment management Reforestation Land-use controls Protection of wetlands Soil conservation Flood management through climate resilient public space (e.g. using floodplains as sports areas) Bush gardens Tree planting to increase shading in community spaces and walkways combating heat stress

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Project	Status	Location	Adaptation Strategies
Flood Resilience in Ulaanbaatar Ger-Areas (FRUGA) Mongolia - Climate Change Adaptation through community-driven small-scale protective and basic services interventions	In Progress	Ulaanbaatar, Mongolia	Reduction of flood risk through resilient urban development and land use management Recycling and treatment of used water Implementation of comprehensive flood prevention measurements such as a flood retention wall, drainage channels, and suitable latrines (for rocky or muddy underground)
Building climate and disaster resilience capabilities of vulnerable and small towns in Lao People's Democratic Republic	In Progress	Lao People's Democratic Republic	Construction of a water treatment plant in each town
Adaptation through small-scale protective and basic service interventions in coastal settlements in Cambodia	In Progress	Cambodia	Mangroves restoration Rehabilitation of 2 canals and prevention of saltwater ingress Bank strengthening work to provide additional water retention and safety, Resilient housing designs developed and demonstrations constructed Green-gray protective infrastructure Improved drainage Rainwater harvesting
Increasing the resilience of displaced persons to climate change-related water challenges in urban host settlements	In Progress	Jordan and Lebanon	Rooftop rainwater harvesting in Lebanon and Jordan Greywater treatment and reuse in Jordan Efficient treatment and reuse of wastewater in Lebanon and Jordan Water-use-efficient irrigation of treated wastewater in Lebanon and Jordan Permaculture demonstration – closed loop water system in Lebanon and Jordan
Urban water harvesting and flood management nexus in Nowshera and Rawalpindi	In Progress	Pakistan	Enhance water harvesting facilities in public buildings Water storage in public gardens These strategies were not directly implemented in informal settlements but in public buildings and spaces in the surroundings of the area.

Table 8. UN-Habitat's projects on nature-based solutions, informality, and climate adaptation from PSUP

Project	Status	Location	Adaptation Strategies
Malawi – Mzuzu (Salisburylines slum): Participatory Slum Upgrading for increased physical resilience	Completed	Mzuzu, Malawi	Upgrading of roads Drainages improvement
Burkina Faso – Ouagadougou (Bissighin slum): Participatory and multi-stakeholder approach for upgrading local alleys and drainage against flooding	Completed	Ouagadougou, Burkina Faso	Construction of drainage structures, particularly drainage roads and steep roads
Ghana– Accra (Jamestown and Ussher Town): Building resilience by using locally available materials	Completed	Accra, Ghana	Permeable paving as an alternative to concrete slabs to improve drainage and sanitation
Haïti – increasing climate resilience through international partnerships and public spaces	Completed	Haiti	Strengthening dykes Coastal protection
Solomon Islands – Honiara (Haekafo): Data-collection and housing durability	Completed	Honiara, Solomon Islands	Resettlement Community gardens
Benin – Cotonou (Protecting coastlines in Benin)	Completed	Cotonou, Benin	Nine concrete and rockfill structures to partially protect the coast
Fiji – Data collection and tenure security	In Progress	Fiji	Refer to "Increasing the resilience of informal urban settlements in Fiji that are highly vulnerable to climate change and disaster risks" in Table 2

Table 9. Private- and public-sector nature-based solution projects and policy approaches

Project / toolbox	Status	Location	Adaptation Strategies
Ecoshape / Building with Nature	Completed	Netherlands and worldwide	Depending on design theme and landscape
Colombia - Beneficial use of dredged material	Completed	Buenaventura, Colombia	Creation of islands in the mouth of Buenaventura Bay Extension of the urban area Use for building materials

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Project / toolbox	Status	Location	Adaptation Strategies
Colombia - NBS for coastal erosion San Andrés	Completed	San Andrés, Colombia	Coral reef restoration Beach replenishment Seagrass restoration Hard underwater protective structures Windbreakers
USA - Staten Island Bluebelt	Completed	New York, NY	Riparian restoration Detention pools Sand filters Native revegetation
USA - Los Angeles County Watershed Management Programs	Ongoing	Los Angeles, CA	Watershed coordination Multi-governance collaboration Water supply and quality solutions
USA - San Francisco Bay Restoration Authority	Ongoing	San Francisco Bay, CA	Coastal and freshwater wetland and riparian habitat restoration Flood protection Shoreline access and recreational amenities Water quality Environmental justice and equity Multi-governance collaboration
England - Princes Lake, Heathrow Airport	Completed	London, England	Water quality Biodiversity management Grassland, forest and wetland habitat restoration Environmental education
Kenya - Integrated Strategic Urban Development Plan	Ongoing	Moyale, Kenya	Water supply evaluation Regional and local water catchment and harvesting design Economic opportunity development
India – Groundwater recharge and supply	Ongoing	Manur and Pappakudi unions, India	Water supply Economic opportunity development
Germany - Flood prevention and habitat restoration	Ongoing	Donaumoos Region, Germany	Flood prevention Carbon sequestration Biodiversity Water management Fen wetland restoration

Youth planting trees in Lilongwe, Malawi (2022)

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