

Building Climate Resilient Cities



May 2023

Written by:
Shweta Pant

Acknowledgements:
Kristie Daniel
Cover Photo: ESAF

TABLE OF CONTENTS

Introduction	1
Climate Change and Public Health	2
Cities and their Vulnerabilities	2
Strategies for Resilience	5
Building Blocks for Resilience	6
Nature-based solutions	6
Community Engagement	6
Public Spaces	6
Policies	7
Incorporate Greenery into Public Spaces	9
Build Resilient Roofs	11
Strengthen Coastal Defences	13
Protect and Restore Urban Wetlands	15
Invest in Blue-Green Infrastructure	17
Create a Stormwater Management Strategy	19
Create Urban Farms	21
Conclusion	23
Selecting the appropriate strategy for building resilience	23
Anticipated Barriers	24
Final Remarks	24
References	25
Appendix A: Summary of Strategies Proposed	32
Appendix B: List of General Resources	36



Photo: Matt Palmer



Photo: NASA

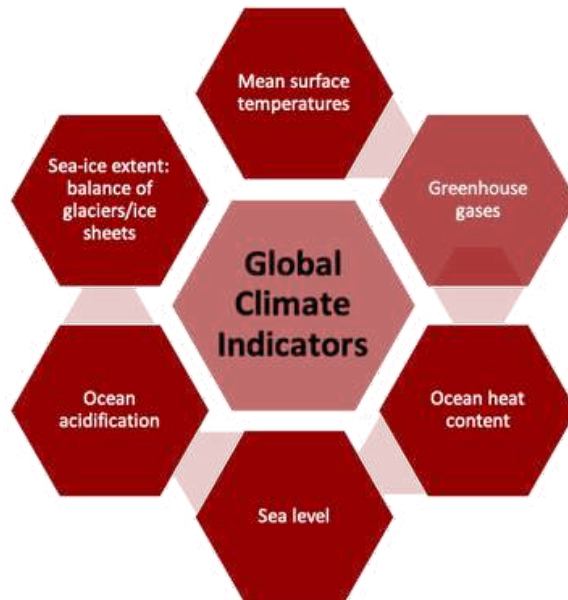


Photo: Patrick Perkins

INTRODUCTION

In recent years, there has been an increasing number of weather disasters, clearly illustrating the threat of a changing global climate and its consequences to global health. Global climate indicators (Figure 1) have been pointing towards a drastically altered climate and its effects are being observed worldwide as increased cases of extreme heat, severe storms, and biodiversity loss are being reported with greater regularity (1,2). With the rise in greenhouse gases (GHG), as a result of a rapidly urbanizing and industrializing world, initiatives such as the Paris Climate Agreement of 2015 are essential in establishing international collaboration to mitigate climate change (2). However recent evidence suggests the targets established in this agreement are not going to be met by participating countries, and vulnerable areas, like cities, will continue to face increased climate-related threats (3). The population density of cities, combined with their built environment makes them especially vulnerable to climate-related disasters (4). Therefore cities urgently to seek resiliency measures that will allow them to withstand the inevitable effects of climate change (5).

Figure 1: A summary of Global Climate Indicators (6)



CLIMATE CHANGE AND PUBLIC HEALTH

Climate change has important impacts on human health. A worsening climate can increase communicable diseases as well as non-communicable diseases, cause deaths in extreme cases, and worsen water scarcity and food insecurity. Extreme heat is a major climate-related concern as it puts a significant burden on human health and health systems, either directly or through the worsening of socioeconomic conditions (1,7). Extreme heat has given rise to vector-borne illnesses such as malaria and dengue fever (2). In addition, extreme heat events are known to kill hundreds of thousands of people each year due to heat strokes and heat exhaustion (7). Extreme heat, combined with increased droughts and fires, give rise to issues such as water scarcity and diminished food production, which results in malnutrition, compromised mental health, hunger, and related health effects (1,2). Meanwhile, other climate events such as floods, typhoons and cyclones cause harm to physical structures rendering homes inhabitable and displacing populations (6).

The impacts of climate change are not equal across the world and factors such as socioeconomic conditions and geography play a large role in determining vulnerability to climate-change-related effects. In areas where conditions are already compromised, extreme climate is exacerbating the situation and worsening the well-being of populations (6). For instance, African countries such as Nigeria, Niger, Chad and Cameroon have high levels of violence and political disturbances. When combined with climate effects such as drought and extreme heat, thousands of people in the region become displaced from their homes (6). Malawi, Mozambique, and Zimbabwe have historically suffered from food insecurity. In 2019, tropical Cyclone Idai destroyed over 780,000 ha of crops and increased food insecurity in these countries (6).

CITIES AND THEIR VULNERABILITIES

Areas with high population densities, such as cities, have a range of socioeconomic conditions and climate weaknesses that make them susceptible to climate-related harm. Cities typically serve as the epicentre for entertainment, employment, government services, transportation, and commercial activities, attracting large numbers of people (4). The continued migration to cities is expected to occur mostly in Asia and Africa with high levels of preexisting inequality and social challenges. This makes these cities highly vulnerable to climate-related disasters (2).

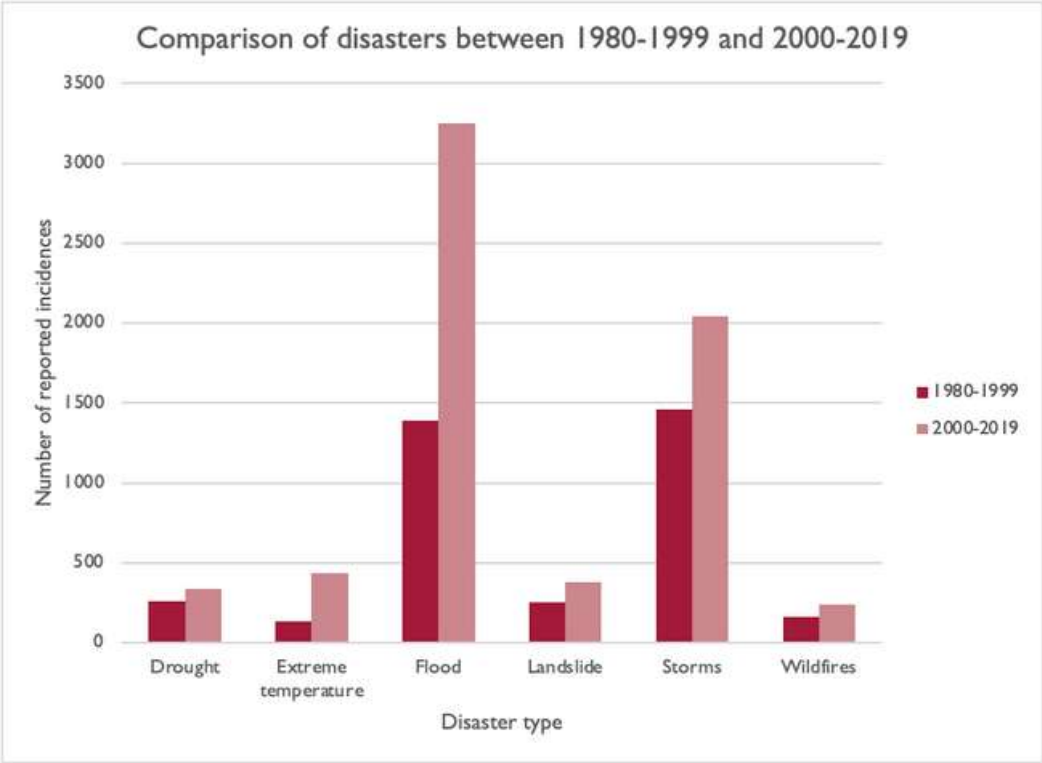
While cities offer opportunities for people, they also consume large amounts of resources, produce enormous amounts of waste, and contribute significantly towards greenhouse gas emissions (9). Cities also contribute to biodiversity loss and climate-related extinctions of various plants and animals (2). Cities contribute to deforestation, as green land is increasingly being used for urban development (2). The loss of greenery is detrimental to biodiversity, climate regulation, and, ultimately, human health.

This loss of biodiversity in cities means many cities typically have little vegetation. That combined with built environments that use grey materials such as concrete and asphalt

paving in their construction (10,11) results in cities that are more susceptible to flooding and increased urban heat island (UHI) effects during warmer months (12). UHI refers to the observation that cities tend to have warmer temperatures than surrounding areas (12). The grey materials used in cities tend to absorb heat during the day and release it into the environment slowly, which contributes to the UHI effect (10, 12). For instance, cities such as New York were found to be 5 degrees Celsius hotter than surrounding areas (12).






Cities, with their high population densities and built environments, are at high risk for experiencing various climate-related disasters. As of 2018 there were 1146 cities with more than 500,000 people (4) and these cities are at risk of at least one kind of climate-related disaster (4). Coastal cities are at high risk of exposure to two or more disasters, and mega-cities are at risk of exposure to more than three types of climate-related disasters (4). Disaster events have seen a marked increase from 2000-2019, as compared to the previous two decades and many of these are related to climate change, depicted in Figure 2 (4).

Figure 2: A comparison of disasters between two time periods (4)



There are five major climate-related risks faced by cities, which would yield harmful outcomes for population health if left unaddressed (Table 1). Cities must assess the risks they will face, and employ strategies accordingly. These risks can be interrelated and impact one another. For example, rising sea levels can increase flooding in cities and threaten biodiversity. Extreme heat can cause droughts and extreme temperatures which can make habitats inhospitable for various plants and animals. An increase in deforestation has an impact on biodiversity loss as well as extreme climate due to trees serving as a natural cooling and habitat for many animals (2). Therefore, resiliency efforts could be targeted against one or more of these risks to help urban populations combat the effects of climate change.

Table 1: A summary of climate-related risks faced by cities

RISK	DESCRIPTION
<p>Extreme heat</p> 	<p>Extreme heat is becoming more common and severe worldwide¹³. Globally, temperature extremes resulted in over 5 million excess deaths per year between 2000 and 2019, and most of this was attributed to extreme heat, depicted in Appendix A¹³. But the impact of extreme weather is unequally felt (Appendix B). Most excess heat-related deaths occurred in crowded, coastal cities of Asia, while smaller proportions of excess deaths were observed in Africa and Europe (Appendix B). Despite varying mortalities, extreme heat is linked to morbidities and mortalities in densely populated cities where the infrastructure creates Urban Heat Islands (UHI)¹². Therefore, cities must adopt resilience strategies to combat the effects of UHI. In conjunction with extreme heat, droughts can also impact cities by drying out vegetation, compromising crop yields and diminishing water supply⁷.</p>
<p>Floods</p> 	<p>Floods are the most common disasters faced by cities⁵. The built environment of cities, characterized by significant amounts of gray infrastructure, creates water accumulation during high precipitation events and renders cities highly susceptible to floods^{9, 11}. Gray infrastructure tends to be impervious and can cause pooling of water, which increases the risk of floods. Regions which are already prone to high precipitation during specific seasons (ex. Monsoon season in Ho Chi Minh City) are likely to be affected by increased flood occurrences⁷.</p>
<p>Storms</p> 	<p>Storms such as cyclones and hurricanes are increasing in intensity and frequency, impacting coastal cities of the world⁷. Reported cases of storms have continued to increase in the past decades and are projected to increase as climate change worsens^{4, 12}. Reduction of natural defenses to storms, such as mangroves, are putting coastal cities at increased risk for damages¹⁴.</p>
<p>Biodiversity loss</p> 	<p>Plants, animals and birds on land and water bodies are experiencing a great deal of stress due to changing habitats⁷. Deforestation and destruction of natural habitats cause the loss of habitats for terrestrial and aquatic habitats¹⁴. On the other hand, ocean warming and acidification have consequences on marine life². Climate change can impact the lives of animals and plants, which in turn affects human health. Animals and plants play a strong role in regulating several diseases such as tick-borne illnesses, and Lyme disease¹⁵. As environment and human health are interconnected, protecting biodiversity is in the best interest of cities.</p>
<p>Rising Sea levels</p> 	<p>Rising sea levels is a major concern to cities surrounded by water and close to sea level. Examples of such cities include Bangkok, Kolkata, Venice, Basra, and New Orleans¹⁷. In addition to risks from rising sea levels, cities like Kolkata also experience immense amounts of rain during their monsoon season, which exacerbates their risk of flooding¹⁶. Meanwhile cities that are already partially underwater, including New Orleans, are highly susceptible to damages by hurricanes¹⁷.</p>

STRATEGIES FOR RESILIENCE

There are no one-size-fits-all solutions for developing climate resilience in cities, as each city will experience different risks and challenges. For instance, coastal cities require protection against rising sea levels, whereas cities near the equator need heat-protection strategies (5). Cities in low and middle-income countries, where increased urbanization is expected, may have less capital to implement changes and require low-cost solutions, whereas cities in higher-income nations could adopt more costly options. Developing appropriate resilience strategies requires a thorough evaluation of climate risks and local conditions must be considered.

Developing climate-resilient cities contributes to several Sustainable Development Goals (SDGs; Figure 3). Of greatest relevance are goals 11 and 13, which pertain specifically to sustainable cities and climate action, respectively (18). However, building climate-resilient cities also has implications for SDG 3 Good Health and Well-Being, as well as SDG 14 Life Below Water and SDG 15 Life on Land 16. In addition, certain aspects of resilient cities also impact SDG 2 Zero Hunger and SDG 9 Industry, Innovation and Infrastructure.

Figure 3: A summary of SDGs impacted by building climate resilient cities.





Building Blocks for Resilience

Resilience includes four important concepts that form the building blocks for any resilience strategy to be successful:

Nature-based solutions (NBS) use natural options to address climate resilience (19,20). They can promote biodiversity and can be low-cost, which means they can address several challenges at once. Since NBS embrace natural defences, they adapt well to changes and help foster the connection between all life forms. In addition to contributing to resiliency, interventions which adopt NBS have demonstrated physical and psychological benefits for human health (20, 21). NBS can face conceptual barriers among policymakers due to a lack of education and the unwillingness to adapt to newer concepts (5,22). There may also be lower funding available for NBS due to outdated building regulations (22). As NBS use natural processes, they can be slow to develop and this could be perceived as an undesirable approach by officials and residents who want results as soon as possible (22,23).

Community engagement enhances social connections, helps disseminate information within communities and assists with disaster relief (20, 24). Involving community members through education helps improve their understanding of climate-related challenges and this can be empowering and help build a resilient community. For example, social connections are highly associated with better outcomes during drastic climate events such as heat waves (20). Social cohesion is considered essential during disaster management and this has been demonstrated during recent disasters such as in post-earthquake in Nepal in 2015 (24). Engaging communities in resiliency efforts gives them a direct role and this could help ensure the longevity and sustainability of resilience strategies.

Public spaces are the spaces in the community where people can come together to connect with other community members, the environment, and their cities (24). Public spaces include places like parks, community centres, public squares, and markets and are the sites where the resiliency interventions are often most appropriate. Public spaces provide the physical spaces where NBS can be implemented, sustainable markets can be promoted, cultural discovery can occur, social cohesion can be enhanced, and disaster relief can take place if needed (24, 23). The examples presented can be employed in the following public spaces, denoted by symbols in Table 2: Streets, Parks, Markets, and Urban agriculture.

Table 2: Symbols associated with public spaces

Public Space	Street	Park	Market	Urban agriculture
Symbol				



Policies, in the form of frameworks, laws, action plans, and strategies are integral when trying to enforce ideas on a large scale. Policies can be useful for building climate resiliency in cities in various ways and scales. For example, a national or regional policy can provide broad guidance on protecting green spaces such as wetlands throughout the country. Meanwhile, local policies can guide infrastructure or disaster planning for governments as well as private companies. Developing policies are an excellent way to address gaps between resilience theory and practice, and they are also a way to assign responsibility (23, 25). For instance, NBS are widely discussed in the literature (1), but their large-scale application is missing in cities due to a long history of established practices, lack of financing and the preconceived negative perceptions of policymakers (22). Incorporating an NBS strategy in city policies will ensure that they can be applied in the community.

Figure 4: The four building blocks of resilience



A few notes on how to navigate through this report

There are seven strategies proposed.

- 1 [Incorporate greenery in public spaces](#)
- 2 [Build Resilient Roofs](#)
- 3 [Strengthen coastal defenses](#)
- 4 [Protect or restore urban wetlands](#)
- 5 [Build hybrid infrastructure](#)
- 6 [Develop a stormwater management strategy](#)
- 7 [Build resilient markets](#)

Each strategy consists of: risks addressed, description, resources and global examples.

Underlined items are hyperlinks.

Risks are identified using symbols presented in *Table 1*.

Public spaces are identified using symbols from *Table 2*.

A summary of the strategies is provided in Appendix C.

Other applicable resources are listed in Appendix D.

1. Incorporate Greenery into Public Spaces

Risks Addressed



Greenery can be incorporated into all public spaces including streets, parks, and markets. Greenery helps cities improve their resilience by supporting climate regulation, improving air quality, and promoting biodiversity (19, 21). Greenery includes trees, shrubs and other forms of vegetation. Trees can absorb water runoff, offer shade, protect against winds, and improve air quality by removing particulate matter and cooling ambient air (9,24, 28). These effects can help reduce the effects of UHI, lessen the demand for air conditioning in cities, and enhance the psychological and physical health of residents (21,28). Tree planting is a popular strategy and there have been numerous tree planting campaigns globally. Tree planting initiatives such as the World Economic Forum’s Trillion Tree Initiative (26) and Plant for the Planet’s Trillion Tree Campaign (27) have global reach and can serve as a great resource when starting a tree planting campaign.

Tree planting costs can vary, ranging from \$10 USD to \$470 USD per tree while constructing other “green” structures can cost thousands of dollars (28,29). The time required for tree growth as well as the potential for some trees to emit harmful compounds, or cause allergies are additional challenges associated with tree planting (28,30). Greenery in general can cause allergic reactions in some people, and it can attract insects which can spread vector-borne illnesses (31). Mass tree planting campaigns have also been known to experience failures due to lack of maintenance and selection of inappropriate species to plant (31).

Plant selection must consider the climate, existing infrastructure, maintenance requirements and cost, as well as species that are native with low allergic potential when possible (30,31). Furthermore, a sustainable maintenance strategy, including involving community members, should be incorporated when adding greenery in public spaces. This will help ensure the longevity and sustainability of the initiative. Organizations such as the United Nations (UN; 32) and the Tree Council (33) have helpful guides on how to plant trees. A popular technique for afforestation, called the Miyawaki Forest technique can also be employed to plant greenery in urban spaces (34). Furthermore, digital technology, such as apps like Tree Mapper, are also available to help monitor the progress of plants in certain regions (35).

Helpful Resources:

Tree Planting Initiatives, including examples

- [World Economic Forum’s trillion trees initiative](#)
- [Trillion Trees Campaign](#)

Guides on how to plant and/or maintain greenery




[Tree Growing for Conservation and Ecosystem Restoration by UN Environment](#)

[Tree and hedge planting step-by-step guide](#)

[World Agroforestry's resources on tree planting](#)

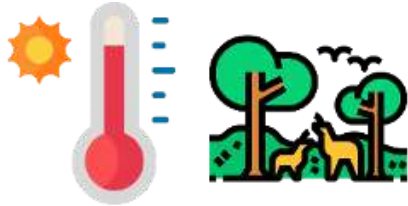
[Miyawaki Method of Afforestation: A how-to guide](#)

[Treemapper website](#)

EXAMPLES	PUBLIC SPACE
<p style="text-align: center;"><u>Green Bus Stops in Poland</u>²⁹</p> <p>Poland has introduced greenery to their existing bus stops. Vegetation and water collection boxes are incorporated on the roof, walls and adjacent areas of the bus stops. The vegetation offers shade, absorbs stormwater and cools the area up to 10C during an extreme heat event. Resiliency and maintenance characteristics and costs were heavily considered in selecting the greenery for this project.</p>	
<p style="text-align: center;"><u>Network of Cool Corridors in Arizona</u>³⁷</p> <p>To curb heat waves, the city of Arizona has developed a plan to create a network of trees and shaded zones so that residents will not be more than 5 minutes away from shade. Tree maintenance is a large part of Arizona's strategy, which ensures the longevity of the shaded structures. This is part of a larger heat action plan in the city, designed to protect residents during extreme heat events.</p>	
<p style="text-align: center;"><u>Freetown the Tree Town Initiative, Sierra Leone</u>³⁸</p> <p>Freetown is the largest city in Sierra Leone and is undergoing rapid urbanization. The Freetown the Tree Town initiative is a city-wide campaign that engaged various community members, non-government organizations (NGOs), and political leaders to identify challenges and develop priorities for the city to focus on. Their initiative includes various strategies, including increasing vegetation coverage by 50% in the city. Their initiative uses open-source technologies to ensure a successful campaign. One app called Treetracker is used to track the progress of tree growth and ensure that the planted trees are being maintained³⁵.</p>	
<p style="text-align: center;"><u>City of Toronto's Urban Forestry Grants and Incentives</u>³⁹</p> <p>The City of Toronto has a goal of covering 40% of the city with trees by 2050. To accomplish this, the city has developed bylaws that protect trees on private and public property. To encourage private homeowners or developers to incorporate greenery in their space, the city also provides grants as monetary incentives.</p>	

2. Build Resilient Roofs

Risks Addressed



Building roofs that can reflect heat is a relatively simple strategy that can cool the inner temperature of buildings, limit energy consumption, and reduce the UHI effect (25). Roofs can be made “green” by incorporating vegetation and plants, which will increase the green footprint of cities. Green roofs reflect solar radiation, absorb CO₂, reduce air pollution, and soak up rainwater. However, green roofs can be expensive and labour-intensive to install or maintain (12, 40). An alternative to green roofs is “cool” roofs, which employ tiles, special materials like polyvinyl chloride, polymer coatings, commercial products or simple, reflective white paint (25). Cool roofs can be low cost and they can be implemented in existing buildings (25). Cool roofs and green roofs can also be combined for maximum effect when possible (41) (Figure 5). Resilient roofs can be incorporated in any public space which requires a roof such as indoor markets or structures in a park.

Figure 5: Benefits of a resilient roof (41)

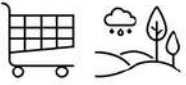

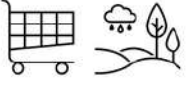



Helpful Resources

[Examples of green roofs in public spaces around the world](#)

[Examples of green roofs in the USA](#)

[Ahmedabad Heat Action Plan](#)

EXAMPLES	PUBLIC SPACE
<p style="text-align: center;"><u>Cool Roofs of Ahmadabad, India</u> ²⁵</p> <p>Ahmedabad, India experiences extreme heat events, which has known to claim lives in the past. The city has developed a heat action plan to address extreme heat events involving community members and organizations. One component of the HAP is the requirement for government buildings to adopt cool roofs in their infrastructure and provide cool roofing for low income housing. The following options are employed to accomplish this:</p> <ol style="list-style-type: none"> 1. Liquid coatings ex. lime wash white paint. 2. Solid cool coatings (ex. PVC, tiles) to existing roofs to increase solar reflectance., Commercial roof systems. 3. Green roofs. 	
<p style="text-align: center;"><u>ModRoof</u> ⁴⁴</p> <p>In India, hundreds of homes have adopted ModRoof, a commercial product created by an Indian company to provide roofing solutions for low income communities⁴⁴. ModRoof is a modular product which offers easy installation and longevity, providing water-proof, fire-resistant, cooling benefits to low income homes. It is created with coconut husk fibers⁴⁴. It has demonstrated ability to decrease internal temperatures by up to 4.5C⁴⁵.</p>	
<p style="text-align: center;"><u>Green Roofs in the Slums of Rio De Janeiro</u> ⁴⁶</p> <p>The Arara region in Rio de Janeiro is densely populated and has little space for planting greenery on a large scale. Hence plants adapted to heat, low nutrition and winds, called lithophytes, were planted on the roofs for low income housing in the slums of Arara. Homes with green roofs were found to be 40% less warmer than those without.</p>	
<p style="text-align: center;"><u>Chicago City Hall's Green Roof</u> ⁴³</p> <p>The City Hall building of Chicago houses a green roof consisting of over 150 species of plants. Evidence informed decision making guided the selection of this green roof to ensure suitable species were planted. This has ensured that the plants can survive in the dynamic temperatures of the city. The green roof offers cooling benefits, stormwater absorption and promotes biodiversity, serving as a great example of how to incorporate greenery in a public building to build resilience.</p>	

3. Strengthen Coastal Defences

Risks Addressed



Nature provides defences in coastal areas in the form of mangroves, sand dunes, and coral reefs (14,47,48). But these natural defences are being destroyed by human activities such as building, aquaculture, and overfishing (47, 48). Strengthening coastal defences requires a multi-pronged approach that includes a comprehensive risk analysis, protection and restoration of natural defences, as well as construction of grey structures such as sea walls (47, 49). These strategies should be reinforced with policies that restrict the construction of buildings close to the coastline and prohibit the use of natural sources, such as mangroves, for resources like fire (47, 48, 49). Restoration of natural entities like mangroves and corals can be costly, so protecting them through policy and educational campaigns is ideal (50).

Mangroves are resilient trees, found near coasts, that naturally provide significant defences against storms, offer habitats for various species, and absorb large amounts of CO₂ (13). Mangrove forests have decreased all over the world over the past decades due to human exploitation of mangrove trees for timber and the destruction of mangrove forests for the expansion of tourism and urban development (13,47). Mangrove restoration projects have demonstrated success and, although expensive, have offered a positive cost-benefit ratio in many coastal cities (14,47). Restoration projects could include recruiting community members to enforce projects such as mass planting of mangrove seedlings, ensuring proper growth conditions for mangrove forests, and educating community members on the important role mangrove forests play in the community (47). Community members can also be involved in the long-term maintenance of mangroves, ensuring sustainability (48).

Coral reefs are underwater organisms that offer storm resilience to coastal communities by reducing wave intensity and trapping harmful sediments (48). There is a significant amount of research being conducted on coral reef restoration strategies, such as breeding species, transplanting species in the ocean, and introducing artificial reefs in degraded areas, which can require significant education and training (50). Coral restoration can be costly, which may not make them a plausible strategy for climate resilience in all cities (50). As such their protection, through policy and education, must be prioritized as a strategy in cities.



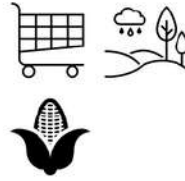
Helpful Resources:

[Ghana: Roadmap for Resilient infrastructure in a changing climate](#)

[Managing Coasts with Natural Solutions](#)

[Mangroves for coastal defence](#)

[Coral Reef Restoration: A guide to coral restoration method](#)

EXAMPLES	PUBLIC SPACE
<p align="center"><u>Coral Reef Restoration Program</u> ⁵¹</p> <p>SECORE is a coral conservation organization whose mandate includes the protection and restoration of coral reefs worldwide. They offer educational opportunities, including a coral restoration training program each year, which teaches coral reef restoration technique. While its feasibility may not be applicable in public spaces, the education they provide can help develop a solid understanding about coral reefs, which are potential NBS in coastal protection.</p>	<p align="center">N/A</p>
<p align="center"><u>Community Led Mangrove Restoration in Cross River State, Nigeria</u> ⁵²</p> <p>Nigeria’s mangrove forests have experienced deterioration because of human activity and the proliferation of invasive species. Strengthened by support from the UN, a community-based organization named REDD has executed an impressive mangrove restoration project in the Cross River Valley. 18 communities have adopted the project, and other states in Nigeria are also beginning a similar project. UN-REDD program includes:</p> <ol style="list-style-type: none"> 1. Education and awareness about mangroves, invasive species, and alternative sources of timber in the community. 2. Development of improved agriculture practices and the creation of a nursery. 3. Created designated areas where mangrove trees could be cut. 	
<p align="center"><u>Collaborative mangrove restoration in Indonesia</u> ⁵³</p> <p>Human activities like aquaculture development and groundwater extraction have resulted in erosion and an imbalance of sediment, compromising mangrove growth in Denman Indonesia. The Indonesian government and members of the public collaborated to create dams made of brushwood to trap harmful sediment to allow surrounding mangrove plants to flourish and be restored. This effort was combined with community education related to sustainable aquaculture practices and the importance of mangroves. This effort, termed “<u>Building with Nature</u>” exemplifies the value of community engagement and the restoration potential of mangroves.</p>	
<p align="center"><u>Nova Scotia’s Coastal Protection Act, 2019</u> ⁵⁴</p> <p>The province of Nova Scotia introduced legislation called the Coastal Protection Act. Community members and experts were consulted to develop this act whose focus is the protection of coastal communities in Nova Scotia. The act entails rules which dictate the distance and height at which new construction would take place. This ensures the safety of the homes being built as well as the protection of natural habitats near coasts.</p>	

4. Protect and Restore Urban Wetlands

Risks Addressed



Wetlands are referred to by many names including swamps, marshes, peatlands, and bogs. These spaces are water-based ecosystems that are essential for aquatic and terrestrial biodiversity. Wetlands can be made of freshwater or saltwater, and they can exist naturally or be human-made (55, 56). They sequester large amounts of carbon, provide a habitat for various flora and fauna, and absorb large amounts of water, offering a reprieve during heightened precipitation (56). In urban areas, wetlands are viewed as wasted space and used as sites for building development and waste disposal (15). As a result, wetlands are replaced with buildings and over-exploited. They have become some of the most threatened ecosystems worldwide (14).

An unhealthy wetland can spread infectious diseases, destroy habitats for multiple species and release the CO₂ it has sequestered, contributing to GHG emissions (15, 56). Therefore, it is in the best interest of cities to protect or restore existing wetlands from pollution and destruction through policy, community education, and collaborations with civil society. Healthy wetlands build resiliency in cities by promoting biodiversity, offering water and carbon absorption functions, and improving aesthetics, which enhances their use as a public space. Urban wetlands can be designated public spaces such as parks.

It is helpful to consider the Ramsar Convention (57), which is an international treaty on wetland protection. The Ramsar Convention provides a wide number of examples of wetlands, guides on how to designate a wetland for protection, and how to maintain wetlands (56). Wetlands International is another organization that is dedicated to wetland protection and management (58). Their website is an excellent resource that provides information on their current projects, case studies and educational material.

Helpful Resources:




[Ramsar Convention](#)

[A handbook for managing wetlands, developed by the Ramsar Convention](#)

[Wetlands International website](#)

[Peatland Assessment](#)

[Global Peatlands Initiative's Report on the state of Peatlands globally](#)

EXAMPLES	PUBLIC SPACE
<p><u>Restoration of a Wetland in Harbin City, China</u>⁶⁰</p> <p>Harbin City, China has been threatened by flooding during monsoon seasons. A wetland in the middle of the city has been redeveloped as a solution to handle high precipitation. The wetland is surrounded by a ring of rocks and ponds, creating a filtration system for the water body. The wetland can absorb large amounts of precipitation during monsoon season. The wetland serves as an urban park and has a network of paths, platforms and seats creating a public space which can be enjoyed by residents of the city. The area is termed a national urban wetland park, which helps the city build resilience against strong precipitation, create an aesthetically pleasing public space, and foster biodiversity in a busy city.</p>	
<p><u>Wetland Restoration with Community Engagement, Collingwood, Ontario</u>⁶¹</p> <p>Shorelines in Collingwood, Ontario consisted of invasive phragmites, which were threatening the marshes. A collaboration between community members and conservation authorities resulted in a massive initiative to remove these invasive species from the shorelines. Over 130 volunteers helped remove 10 metric tons of the invasive species over two years. This initiative demonstrates the impact of community engagement in the protection of wetlands.</p>	
<p><u>Jurong Lake Gardens, Singapore</u>⁶²</p> <p>Jurong Lake Gardens, situated in an urban area, was once a swamp and has now been expanded to include the original wetland, grassland, walking areas, activity areas for all ages, and an educational centre in Singapore. The large garden also offers regular events and programs to attract community members to use the space. Jurong Lake Gardens is a re-imagined wetland incorporated into a major urban centre where community engagement can occur, where biodiversity is promoted and that provides a reprieve from busy city life.</p>	

5. Invest in Blue Green Infrastructure (BGI)

Risks Addressed



Blue-green infrastructure (BGI), also called hybrid infrastructure or nature-based infrastructure (NBI), uses nature, such as waterways and greenery, in order to create the structures needed to serve the functions of a city. BGI can be used along with grey infrastructure, which includes engineered structures such as paved roads, sewers, bridges, and sea walls. Grey infrastructure can often be impervious, and heat absorbing and can contribute towards the UHI effect (41, 63). Some grey infrastructure is necessary for building structures in cities, but grey infrastructure can be costly to implement and maintain (41). There are ways to adapt grey structures to become more climate-friendly, such as using reflective materials that repel heat or using porous materials to build roads (63). However, these types of solutions do not provide the same benefits as BGI. BGI has widespread benefits for the environment, costs relatively less to implement, promotes biodiversity and, in some cases, can adapt to changing environments (41,64). The challenges associated with BGI include the length of time needed for it to establish and it cannot replace all the functions that grey structures serve (64).

A hybrid design that uses grey infrastructure with natural components is a suitable way to build resilience in cities as the combination of the two can counteract the others' shortcomings (64). For instance, using high-reflective coating in a building can be combined with greenery to offer a multiplied cooling effect during extreme heat events (41). BGI can often offer numerous benefits to the community such as cooling, aesthetics and enhanced psychological health (41, 65, 66). BGI can be particularly useful in coastal protection (64). Growing mangroves and coral restoration can take time to grow, so building human-made structures like sea walls or dykes can provide benefits in the short term while the green infrastructure is growing (65, 66).


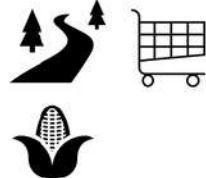

BGI can be implemented in any public space. BGI can provide many benefits such as water retention during high precipitation, improved air quality and biodiversity, improved health effects, and reduced UHI (66). Furthermore, BGI has also been found to be cheaper than grey infrastructure and the aesthetics offered by BGI can increase property values, which can be an appealing quality when convincing government officials and policymakers (66).

Helpful Resources:

[Examples of hybrid infrastructure from around the world](#)

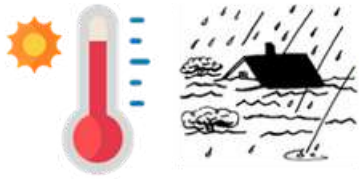
[Simple examples of BGI](#)

A guide on Blue Green Infrastructures, which bridges the gap between BGI theory and practice using examples from Europe: [A roadmap for the BGI Manual](#).

EXAMPLES	Public Space
<p align="center"><u>New York’s Coastal Resilience Plan</u> ⁶⁹</p> <p>Following Hurricane Sandy, New York City recognized the need to protect its coast and developed an action plan that included a hybrid approach. A comprehensive analysis of the effects of the storm identified that elevation, natural items such as sandy beaches and constructed structures like bulkheads worked to minimize storm impact in several neighbourhoods. Applying these examples on a larger scale, NYC’s coastal protection strategy adopts a multi-faceted plan incorporating built structures such as floodwalls, levees and bulkheads along with an enhancement of natural systems such as beaches, wetlands and reefs.</p>	
<p align="center"><u>Kampung Admiralty Building in Singapore</u> ⁷⁰</p> <p>Kampung Admiralty Building houses residents. It incorporates sustainability and resilience in its design. Multiple levels of the building include greenery that serves as rain gardens, bioswales to gather storm runoffs, and a stormwater reserve. The greenery provides cooling features during heat events in addition to serving as a common place to allow for social interactions. While this example is that of a private residence, the concept can be applied to public spaces such as indoor parks or markets.</p>	
<p align="center"><u>Blue-Green Infrastructure in Vancouver’s Urban Design</u> ⁷¹</p> <p>As part of Vancouver’s strategy to manage high precipitation, the city has employed a variety of blue-green initiatives in public spaces. Examples include green roofs, rain-friendly streets created with porous pavement and trees, and bioswales and rain gardens alongside roads. The city’s grey structures are also modified so they support the growth of greenery. For instance, under paved surfaces, an underdrain is created so that water runoffs can be directed to soil layers instead of stormwater drains to support plant growth.</p>	

6. Create a Stormwater Management Strategy

Risks Addressed



Stormwater management systems are an important strategy that should be incorporated when trying to build resilience in cities, especially for cities at high risk of floods. Stormwater management strategies have different names – Sponge City in China, Low Impact Development (LID) in North America, and Sustainable Drainage System in the United Kingdom (72). The concept behind such systems is to incorporate as many features as possible to help the ground absorb rainwater (72). Stormwater strategies should incorporate nature-based solutions such as vegetation and bioswales, which naturally absorb water (66). However, porous grey materials, such as porous asphalt and tiles, also have a place in managing stormwater (73). Physical structures can be built for resiliency by using methods such as stormwater reserve tanks, modified roads, and dikes. Altogether, these measures can contribute towards stormwater management in public spaces such as parks, streets and even infrastructure for markets.

Various places around the world have guidelines on how to incorporate stormwater management in construction, which can be helpful for those who require assistance incorporating it into their plan. For instance, the Ontario Ministry of Environment, Conservation, and Parks in Canada has developed a guide to help plan a LID (75), which could be beneficial to guide policies for cities. There are also American resources which provide guides on how to develop LID (74). These guides can be useful for residents and local community organizations who would like ideas on which porous materials they can utilize to enhance stormwater management in their cities.


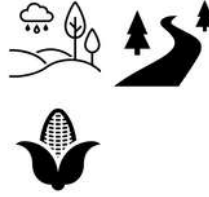

Helpful Resources:

[LID Management Guidance Document from Ontario, Canada’s Ministry of Environment, Conservation and Parks](#)

[List of LID guides from America](#)

[Sponge cities and examples](#)

A comprehensive strategy and stormwater management framework developed to address the high incidences of floods experienced along the Msimbazi river in Dar E Salaam, Tanzania: [“The Mimbazi Opportunity”](#)

EXAMPLES	Public Space
<p><u>Stormwater Reserves that Function as a Skatepark for the Community</u>⁷⁸</p> <p>An industrial area in the city of Roskilde, Denmark has been transformed into a large concrete park incorporating a rainwater collection system. The rainwater is collected through a water canal which opens into a bowl that collects rainwater during storms. The design of this structure allows for the park to be used as a skatepark when dry, attracting people who like to skateboard to gather and use the space for recreation.</p>	
<p><u>Room for the River Project</u>⁷⁹</p> <p>Several cities in the Netherlands are surrounded by rivers that are prone to flooding. The Dutch government enacted a national “Room for the River” project, which involved the alteration or construction of various structures around cities to allow for water to flow through safely in case of flooding. The concept was designed to allow flood waters to pass through the city safely without damaging people or property. The success of the project has also inspired other cities facing similar flooding risks, such as Los Angeles. (90)</p>	
<p><u>The Avalon Green Alley Network Demonstration Project</u>⁸⁰</p> <p>The city of Los Angeles devised a project titled “Green Alleys” to convert previously neglected and/or unsafe alleyways into safe, climate-resilient spaces for communities. These alleys include permeable materials in their construction, bioswales and greenery to promote community usage. The green alleys can help alleviate the UHI, help manage stormwater runoffs and even provide space for green transportation such as bicycling or walking.</p>	

7. Create Urban Farms

Risks Addressed



Urban markets are the main source of food distribution in many cities and are therefore a critical part of city infrastructure (81). Urban markets can be affected by climate change. Climate extremes such as extreme heat and droughts can degrade soil quality and affect crop yields while storms can destroy crops (81) and urbanization destroys land that could be used for agriculture, creating long distances between communities from farms (83). These factors impact the foods that are sold in markets and, as a result, the food supply for cities becomes increasingly at risk.




Urban agriculture has the potential to help communities create a more resilient food supply close to home and this strategy has been increasing in popularity (82). Urban agriculture minimizes the need for food to be transported and helps decrease food insecurity (82, 66). It has also been found to demonstrate the potential to increase employment and enhance community engagement (66,82). Projects can include smaller-scale urban gardens to larger urban farms and both can provide food for households and for communities (82, 83). Urban agriculture can be adapted in many ways including rooftops, vertical farming, and backyards (82). Urban agriculture can range from small-scale, uncontrolled projects to large, controlled food production (82). While large-scale projects can require larger levels of capital, significant cost-benefit analysis, and heavy coordination, small-scale urban farming can be implemented with support from NGOs and local governments (82).

Urban agriculture can promote biodiversity, absorb water during increased precipitation and help alleviate UHI by increasing greenery. There are guides that can help communities get started on formulating a plan. Urban gardens can be employed in various public spaces such as parks, markets, and, in some cases, alongside streets. If possible, they should employ blue-green infrastructure in their planning and implementation.

Helpful Resources:

[A guide on how to start a community garden](#)

[Examples of urban gardens in large cities](#)

EXAMPLES	Public Space
<p style="text-align: center;"><u>Urban Agriculture Project in Rosario, Argentina</u>⁸⁶</p> <p>In Rosario, Argentina, an urban agriculture program in 2001 was originally created to battle political disturbances, high unemployment, and food insecurity. The program equipped residents with education, tools and seeds to start a garden in abandoned areas, which gained popularity amongst local residents. Products from the urban agricultural gardens could be consumed by residents or were sold in markets created specifically for these products. The program was very successful and it continues to be highly active today. These urban gardens increase climate resilience by providing high absorptive abilities during high precipitation, and they also have important social benefits as they program addresses food insecurity and employment.</p>	
<p style="text-align: center;"><u>Transformation of a Rubbish Dump in Cape Town, South Africa</u>⁸⁷</p> <p>In conjunction with UNICEF South Africa and a local arts company, residents near Salt River came together to transform a space used for dumping waste. In a collaborative effort, the dumping site was cleaned up and transformed into a playground and a community vegetable garden adorned by local artwork. This pilot project engaged community members, offered greenery in a previously wasted space and helped grow food items for residents. This project could be expanded into other areas and offers both climate resiliency and social benefits.</p>	
<p style="text-align: center;"><u>The Multiple Benefits of Green Roof at Jacob Javits Convention Center, New York</u>⁸⁸</p> <p>The Jacob Javits Convention Center, located in Manhattan, New York, has incorporated greenery in its existing grey design. The roof was modified to include a farm that grows about 50 crops and thousands of fruits and vegetables. The products of this farm are used for meals in the convention center. Furthermore, the green space is used as a space for public use, offers cooling effects during extreme heat events, and provides habitat for several types of birds, bees and insects. It also serves as a center for research. The greenery absorbs 75% of rainwater that falls and reduces the heat consumption of the building by 46%.</p>	

Conclusion

Selecting the appropriate strategy for building resilience

When considering employing a strategy, it is essential to start by understanding what resiliency looks like in the city where the work is occurring. Established organizations such as the C40 network provide examples of risks faced by cities and how to address those risks (89). Rockefeller Foundation's Framework on City Resilience (90) is another helpful resource for getting started. Selecting a resilience strategy to employ in cities must consider 3 important factors: identification of risks, resources, and sustainability (Figure 6).

Figure 6: Important factors in selecting strategies for resilience



Identification of risks. A city can experience one or more risks listed in Table 1, which will help identify the strategy required. A coastal city is likely to face more climate risks that include storms and sea level rise (4, 5). Whereas increased temperatures, floods or biodiversity can be experienced by all cities. When connecting a strategy with risks, it is also important to note that the examples presented include multiple strategies and therefore have multiplied benefits for cities. For example, Harbin Park in China is included as an example of urban wetland protection but it is also an example of stormwater management and incorporating greenery in public space. The Avalon Green Alley Project exemplifies blue-green infrastructure (BGI), greenery in public spaces, and stormwater management. The examples can also be applied in diverse settings. For example, the idea of a green bus stop can be applied to markets or public parks with shaded structures. Risk identification tools such as UN-Habitat's City Resilience Action Planning Tool can be highly beneficial at this stage. Risk identification can help pick strategies to start thinking about.

Resources. A city should consider the resources available to address climate resiliency. Resources include public spaces, financing, staffing, and education/training. Financing and educational resources can come from a variety of sources such as governments, non-government organizations, and the community. For example, the mangrove restoration project in Cross River State in Nigeria received support from UN-REDD, whereas the urban agriculture project in Rosario, Argentina was initially funded by the government. In terms of the staffing needed to carry out the strategies, these initiatives can be done by government offices, private companies, and with community engagement. The wetland restoration project in Collingwood, Ontario was implemented by members of the community whereas the construction of green bus stops in Poland hired a construction company. The public space symbols in the examples provided can be used to assess the public space where strategies can be best employed.

Sustainability. The sustainability of the strategy is another important factor to consider, especially if nature-based solutions (NBS) are used. NBS such as green roofs or tree planting will require maintenance for them to thrive and provide the needed effects. Engaging community members and educating them on the value of resilience strategies can be an excellent way to ensure sustainability, but monetary incentives can also be valuable. If the strategy generates revenue for community members, sustainability can be enhanced. For example, Rosario, Argentina’s urban farming initiative helps community members gain employment.

Anticipated Barriers

Some barriers to be anticipated when implementing a resilient strategy include costs, lack of knowledge, lack of political will, and existing contractual obligations in construction (5, 21). The largest barrier pertains to the adoption of NBS in practice. NBS have garnered significant attention in research, but its large-scale application is still lacking. Hence, currently, NBS does not receive as much financing as required to mitigate climate change effects, and this can affect resiliency initiatives in cities (91). In addition, policy-makers who are not aware of NBS could have incorrect assumptions about incorporating actions such as BGI, as opposed to traditional grey infrastructure (21). If building codes are outdated and require the use of grey infrastructure, it also poses a barrier to implementing NBS or permeable alternatives. NBS can also take time to develop, and this can conflict with project timelines (21).

Final remarks

Each city is unique in its geography, demographics, and social conditions; hence each city must adopt strategies that suit its needs. Building resilience in cities is urgent. Cities should investigate incorporating suitable strategies immediately. Any opportunity to advocate for resilience in policies must be taken, as they will ultimately guide action and bring theory into practice (92). Policies will help ensure that resilience can be incorporated before construction projects begin (5). The resilience strategies proposed here can also be used post-disaster. There is often a need to re-build quickly after a disaster event. However, it is essential that resilient strategies, such as resilient roofs and BGI, be considered when rebuilding (5). Disaster relief can be extremely costly, and resilience can prevent climate disasters from causing extensive damage to infrastructure and human life, ultimately proving to be cost-effective (5, 93).

The benefits of a resilient city are enormous and positively affect economies, the well-being of people, and biodiversity. A resilient city addresses several SDGs, adding further benefits (Appendix A). It is important to note that adopting strategies to build a resilient city will not remove challenges related to climate change, nor will they fix social determinants of health on a grand scale (93). But working towards building a climate-resilient city will ensure that communities are prepared to withstand climate-related challenges better, and cities can become more livable for current and future populations.

References

1. Intergovernmental Panel on Climate Change. Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.; 2019. <https://doi.org/10.1017/9781009157940>.
2. Fawzy S, Osman AI, Doran J, Rooney DW. Strategies for mitigation of climate change: a review. *Environmental Chemistry Letters*. 2020;18(18):2069-2094. doi:<https://doi.org/10.1007/s10311-020-01059-w>
3. World Economic Forum. The Global Risks Report 2022, 17th Edition.; 2022. <https://www.weforum.org/reports/global-risks-report-2022>
4. United Nations, Population Division. The World's Cities in 2018 - Data Booklet.; 2018. <https://digitallibrary.un.org/record/3799524>
5. The Center for Climate and Energy Solutions. What Is Climate Resilience and Why Does It Matter?; 2019. <https://www.c2es.org/document/what-is-climate-resilience-and-why-does-it-matter/>
6. World Meteorological Organization. WMO Statement on the State of the Global Climate in 2019.; 2020. https://library.wmo.int/index.php?lvl=notice_display&id=21700
7. McKinsey Global Institute. Climate Risk and Response: Physical Hazards and Socioeconomic Impacts.; 2020. <https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts>
8. Esprit Smith. Human Activities Are Drying Out the Amazon: NASA Study – Climate Change: Vital Signs of the Planet. *Global Climate Change: Vital Signs of the Planet*. Published November 5, 2019. <https://climate.nasa.gov/news/2928/human-activities-are-drying-out-the-amazon-nasa-study/>
9. United Nations Environment Programme. Smart, Sustainable and Resilient Cities: The Power of Nature-Based Solutions.; 2021. <https://wedocs.unep.org/bitstream/handle/20.500.11822/36586/SSRC.pdf?sequence=1&isAllowed=y>
10. Orsetti E, Tollin N, Lehmann M, Valderrama VA, Morató J. Building Resilient Cities: Climate Change and Health Interlinkages in the Planning of Public Spaces. *International Journal of Environmental Research and Public Health*. 2022;19(3):1355. doi:<https://doi.org/10.3390/ijerph19031355>
11. Ajjur SB, Al-Ghamdi SG. Exploring urban growth–climate change–flood risk nexus in fast growing cities. *Scientific Reports*. 2022;12(1). doi:<https://doi.org/10.1038/s41598-022-16475-x>
12. Heaviside C, Macintyre H, Vardoulakis S. The Urban Heat Island: Implications for Health in a Changing Environment. *Current Environmental Health Reports*. 2017;4(3):296-305. doi:<https://doi.org/10.1007/s40572-017-0150-3>

13. Zhao Q, Guo Y, Ye T, et al. Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study. *The Lancet Planetary Health*. 2021;5(7):e415-e425. doi:[https://doi.org/10.1016/s2542-5196\(21\)00081-4](https://doi.org/10.1016/s2542-5196(21)00081-4)
14. Blankespoor B, Dasgupta S, Lange GM. Mangroves as a protection from storm surges in a changing climate. *Ambio*. 2016;46(4):478-491. doi:<https://doi.org/10.1007/s13280-016-0838-x>
15. Wildfowl & Wetlands Trust. Ramsar Wetland Disease Manual: Guidelines for Assessment, Monitoring and Management of Animal Disease in Wetlands.; 2012. <https://www.wwt.org.uk/our-work/wetland-conservation-unit/publications/ramsar-wetland-disease-manual/>
16. BLACK PF, BUTLER CD. One Health in a world with climate change. *Revue Scientifique et Technique de l'OIE*. 2014;33(2):465-473. doi:<https://doi.org/10.20506/rst.33.2.2293>
17. Broom D. Around the world, these are just some of the cities at risk of rising sea levels. World Economic Forum. Published December 2, 2021. <https://www.weforum.org/agenda/2021/12/coastal-cities-underwater-climate-change/>
18. United Nations. The 17 Sustainable Development Goals. United Nations. Published 2015. <https://sdgs.un.org/goals>
19. Mukherjee M, Wickramasinghe D, Chowdhoree I, et al. Nature-Based Resilience: Experiences of Five Cities from South Asia. *International Journal of Environmental Research and Public Health*. 2022;19(19):11846. doi:<https://doi.org/10.3390/ijerph191911846>
20. Kristie D, Strickland E. Policies That Support Parks and Open Public Spaces: Global Examples. HealthBridge; 2017.
21. Kolokotsa D, Lilli AA, Lilli MA, Nikolaidis NP. On the impact of nature-based solutions on citizens' health & well being. *Energy and Buildings*. 2020;229:110527. doi:<https://doi.org/10.1016/j.enbuild.2020.110527>
22. The Center for Climate and Energy Solutions. What Is Climate Resilience and Why Does It Matter?; 2019. <https://www.c2es.org/document/what-is-climate-resilience-and-why-does-it-matter/>
23. Guardaro M, Messerschmidt M, Hondula DM, Grimm NB, Redman CL. Building community heat action plans story by story: A three neighborhood case study. *Cities*. 2020;107:102886. doi:<https://doi.org/10.1016/j.cities.2020.102886>
24. Daniel K. Public Spaces: A Key Tool to Achieve the Sustainable Development Goals.; 2016.
25. Dutta P. Ahmedabad Heat Action Plan: Guide to Extreme Heat Planning in Ahmedabad, India.; 2019. <https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf>
26. World Economic Forum. 1t.org: Progress Report.; 2022. <https://weforum.ent.box.com/s/lj6wii227u9e4tv5y7fii0y51bsgl1q>

27. Plant For The Planet. The Trillion Tree Campaign. Trilliontreecampaign.org. Published 2020.
<https://www.trilliontreecampaign.org/>
28. Akbari H. Shade trees reduce building energy use and CO2 emissions from power plants. *Environmental Pollution*. 2002;116:S119-S126. doi:[https://doi.org/10.1016/s0269-7491\(01\)00264-0](https://doi.org/10.1016/s0269-7491(01)00264-0)
29. LIFE Tree Check. Green Bus Stops. www.lifetreecheck.eu. Published 2023.
<https://www.lifetreecheck.eu/en/Databaze/2019/Green-Bus-Stops>
30. van den Bosch M, Ode Sang Å. Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews. *Environmental Research*. 2017;158:373-384.
doi:<https://doi.org/10.1016/j.envres.2017.05.040>
31. Fleischman F, Basant S, Chhatre A, et al. Pitfalls of Tree Planting Show Why We Need People-Centered Natural Climate Solutions. *BioScience*. 2020;70(11). doi:<https://doi.org/10.1093/biosci/biaa094>
32. D’Arcy L, Diederichsen A, Elkin C, Barasa T. Tree Growing for Conservation and Ecosystem Restoration: A Guide for Faith-Based Actors.; 2022. <https://www.decadeonrestoration.org/publications/tree-growing-conservation-and-ecosystem-restoration-guide-faith-based-actors>
33. The Tree Council. Tree and Hedge Planting – a Step-By-Step Guide.; 2021. <https://treecouncil.org.uk/wp-content/uploads/2022/12/The-Tree-Council-Planting-Guidance.pdf>
34. Spicetree Munnar. A Complete Guide To The Miyawaki Method. SpiceTree Munnar. Published November 18, 2021. <https://spicetreemunnar.com/complete-guide-miyawaki-method/>
35. Plant for the Planet. TreeMapper. Plant-for-the-Planet. <https://www.plant-for-the-planet.org/treemapper/>
36. World Agroforestry. Global Tree Knowledge Platform. Published 2021. <https://www.worldagroforestry.org/tree-knowledge>
37. Araiza C. How America’s hottest city will survive climate change. *Washington Post*. Published July 8, 2020.
<https://www.washingtonpost.com/graphics/2020/climate-solutions/phoenix-climate-change-heat/>
38. Freetown City Council. Transform Freetown: An Overview, 2019-2022.; 2022. <https://fcc.gov.sl/wp-content/uploads/2019/01/Transform-Freetown-an-overview.pdf>
39. City of Toronto. Tree Planting. Published April 27, 2018. <https://www.toronto.ca/services-payments/water-environment/trees/tree-planting/>
40. Thapa S, Nainabasti A, Bharati S. Assessment of the linkage of urban green roofs, nutritional supply, and diversity status in Nepal. Tejada Moral M, ed. *Cogent Food & Agriculture*. 2021;7(1):1911908.
doi:<https://doi.org/10.1080/23311932.2021.1911908>
41. Andersson E, Grimm NB, Lewis JA, et al. Urban climate resilience through hybrid infrastructure. *Current Opinion in Environmental Sustainability*. 2022;55:101158. doi:<https://doi.org/10.1016/j.cosust.2022.101158>





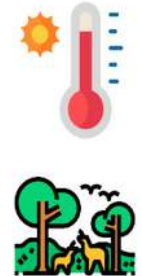

42. The Guardian. Urban oases: green roofs around the world – in pictures. The Guardian. <https://www.theguardian.com/cities/gallery/2018/aug/17/urban-oases-green-roofs-around-the-world-in-pictures>. Published August 17, 2018.
43. Roofed Right America. Commercial & Industrial Flat Roofing Contractors: Installation, Repair & Inspection Services for Flat roofs, Sloped roofs, Solar Panels & and Green Roofs. www.roofedright.com. Published 2023. <https://www.roofedright.com/Services/CommercialGreenRoofs/Examples>
44. Engineering for change. ModRoof. Engineering For Change. Published 2023. <https://www.engineeringforchange.org/solutions/product/modroof/>
45. Dutta P, Vellingiri S, Singh S, Sathish L, Pingle S, Brahmabhatt B. Combating climate change-induced heat stress: Assessing cool roofs and its impact on the indoor ambient temperature of the households in the Urban slums of Ahmedabad. *Indian Journal of Occupational and Environmental Medicine*. 2020;24(1):25. doi:https://doi.org/10.4103/ijoem.ijoem_120_19
46. Conexus. Green roofs in the slums of Rio de Janeiro, Brazil. Oppla. Published November 30, 2021. <https://oppla.eu/casestudy/23397>
47. Spalding M, Mclvor A, Tonneijck F, Tol S, van Eijk P. Mangroves for Coastal Defence Guidelines for Coastal Managers & Policy Makers. Wetlands International and The Nature Conservancy.; 2014. <http://www.nature.org/media/oceansandcoasts/mangroves-for-coastal-defence.pdf>
48. World Bank Group. Managing Coasts with Natural Solutions : Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs.; 2016. <https://openknowledge.worldbank.org/entities/publication/84239b95-baec-5951-9fd3-a32c769d8828>
49. Adshead D, Thacker S, Fuldauer LI, et al. Ghana: Roadmap for Resilient Infrastructure in a Changing Climate. Ministry of Environment, Science, Technology & Innovation, Accra, Ghana.; 2022. <https://gca.org/reports/ghana-roadmap-for-resilient-infrastructure-in-a-changing-climate/>
50. Hein M, McLeod I, Shaver E, et al. Coral Reef Restoration as a Strategy to Improve Ecosystem Services – a Guide to Coral Restoration Methods. United Nations Environment Program; 2020. <https://wedocs.unep.org/handle/20.500.11822/34810>
51. Secore International. SECORE International. www.secore.org. <http://www.secore.org/site/education.html>
52. Dierckxsens GI. Mangrove Rehabilitation in Nigeria. UNREDD Programme. Published January 2, 2020. <https://www.un-redd.org/stories-of-change/mangrove-rehabilitation-nigeria>
53. Wetlands International. Building with Nature Indonesia. Wetlands International Indonesia. Published April 10, 2016. <https://indonesia.wetlands.org/casestudy/building-with-nature-indonesia/>
54. Office of the Legislative Counsel, Nova Scotia House of Assembly. Coastal Protection Act.; 2019. https://nslegislature.ca/legc/bills/63rd_2nd/1st_read/b106.htm






















55. Government of Canada. Nature-based climate solutions. canada.ca. Published February 20, 2023. https://www.canada.ca/en/services/environment/our-environment/nature-based-climate-solutions.html?utm_campaign=eccc-eccc-nbs-22-23&utm_medium=sem&utm_source=bing&utm_content=ad-text-en&utm_term=wetlands&adv=2223-385400&id_campaign=698040808&id_source=1256742436158093&id_content=78546566000572&gclid=f151eb b98af21c46566e884305002ffd&gclsrc=3p.ds&
56. Ramsar Convention Secretariat. Managing Wetlands: Frameworks for Managing Wetlands of International Importance and Other Wetland Sites. Ramsar Convention Secretariat; 2010.
57. Ramsar Convention Secretariat. Introducing the Convention on Wetlands Working Together for Wetlands.; 2014. https://www.ramsar.org/sites/default/files/documents/library/introducing_ramsar_web_eng.pdf
58. Wetlands International. Our Work. Wetlands International. <https://www.wetlands.org/our-work/>
59. UNEP. Global Peatlands Assessment – the State of the World’s Peatlands: Evidence for Action toward the Conservation, Restoration, and Sustainable Management of Peatlands. Main Report.; 2022. https://globalpeatlands.org/sites/default/files/2022-12/peatland_assessment.pdf
60. Turenscape. Harbin Cultural Center Wetland Park. www.turenscape.com. Published July 2, 2014. <https://www.turenscape.com/en/project/detail/4625.html>
61. Ramsar Convention Secretariat. CEPA Story: 10,000 kilograms of invasive “Phragmites” were removed from Collingwood’s Coastal wetlands in Canada thanks to community action. | Convention on Wetlands. www.ramsar.org. Published December 16, 2016. Accessed April 2, 2023. <https://www.ramsar.org/news/cepa-story-10000-kilograms-of-invasive-phragmites-were-removed-from-collingwoods-coastal>
62. Ramboll group. Lakeside Garden. Ramboll Group. Published 2019. Accessed April 2, 2023. <https://ramboll.com/projects/singapore/lakeside-garden>
63. Joint Nature Conservation Committee. › Roadmap for the BGI Manual.; 2019. <https://data.jncc.gov.uk/data/354f40aa-1481-4b7f-a1eb-82c806893409/BGI-Manual-Report.pdf>
64. Morris RL, Boxshall A, Swearer SE. Climate-resilient coasts require diverse defence solutions. Nature Climate Change. 2020;10(6):485-487. doi:<https://doi.org/10.1038/s41558-020-0798-9>
65. Sutton-Grier AE, Wowk K, Bamford H. Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. Environmental Science & Policy. 2015;51:137-148. doi:<https://doi.org/10.1016/j.envsci.2015.04.006>
66. Bechauf R, Cutler E, Bassi A, et al. The Value of Incorporating Nature in Urban Infrastructure Planning. International Institute for International Development; 2012. <https://www.iisd.org/publications/report/nature-in-urban-infrastructure-planning>
67. CNN Staff. Green buildings: 18 examples of sustainable architecture around the world. CNN. Published April 24, 2020. <https://www.cnn.com/style/article/green-buildings-world-sustainable-design/index.html>







68. Dolman N, O'Donnell E. 5 lessons learned from blue-green infrastructure delivery. Institution of Civil Engineers Blog. Published July 6, 2021. <https://www.ice.org.uk/news-and-insight/the-civil-engineer/july-2021/theory-and-practice-of-blue-green-infrastructure>
69. City of New York. 2013 Plan: A Stronger, More Resilient New York.; 2013. https://a860-gpp.nyc.gov/concern/nyc_government_publications/37720d67f
70. Beng YC. Kampung Admiralty: Building for All Ages. Civil Service College. Published April 29, 2019. <https://www.csc.gov.sg/articles/kampung-admiralty-building-for-all-ages>
71. City of Vancouver. Green infrastructure: sustainably managing our rainwater. Vancouver.ca. Published October 18, 2017. <https://vancouver.ca/home-property-development/green-infrastructure.aspx>
72. Wang Y, Jiang Z, Zhang L. Sponge City Policy and Sustainable City Development: The Case of Shenzhen. *Frontiers in Environmental Science*. 2022;9. doi:<https://doi.org/10.3389/fenvs.2021.772490>
73. Clements J, St A, Juliana, Julianaauthor J, Clements A, St. NRDC: The Green Edge - How Commercial Property Investment in Green Infrastructure Creates Value (PDF).; 2013. <https://www.nrdc.org/sites/default/files/commercial-value-green-infrastructure-report.pdf>
74. Ontario Ministry of the Environment, Conservation and Parks. Low Impact Development Stormwater Management Guidance Manual: Draft for Consultation.; 2022. <https://ero.ontario.ca/notice/012-9080#:~:text=The%20purpose%20of%20the%20LID%20Guidance%20Manual%2C%20once,municipalities%2C%20conservation%20authorities%2C%20land%20developers%20and%20their%20consultants.>
75. US EPA. Green Infrastructure Design and Implementation | US EPA. US EPA. Published July 25, 2018. <https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation>
76. Peters A. How “sponge cities” are redesigning themselves for extreme rain. *Fast Company*. https://www.fastcompany.com/90832580/how-sponge-cities-are-redesigning-themselves-for-extreme-rain?utm_source=pocket-newtab. Published January 10, 2023.
77. Dar es Salam. Volume B Detailed Plan for the Lower Basin the Msimbazi the Msimbazi Opportunity Opportunity Transforming the Msimbazi Basin into a Beacon of Urban Resilience Public Disclosure Authorized Public Disclosure Authorized Public Disclosure Authorized Public Disclosure Authorized.; 2019. <https://documents1.worldbank.org/curated/en/448681555397287820/pdf/Volume-B-Detailed-Plan-for-the-Lower-Basin.pdf>
78. Stinson L. Ingenious Architecture: A Skatepark That Prevents Flooding. *Wired*. Published June 25, 2014. <https://www.wired.com/2013/06/innovative-infrastructure-a-skate-park-that-prevents-flooding/>
79. Dutch Water Sector. Room for the River explained | Dutch Water Sector. www.dutchwatersector.com. Published July 29, 2021. <https://www.dutchwatersector.com/news/room-for-the-river-explained>
80. Lindt R. The Avalon Green Alley Network Demonstration Project: Lessons Learned from Previous Projects for Green Alley Development in Los Angeles & Beyond.; 2015. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/The_Avalon_Green_Alley_Network_Demonstration_Project.pdf




81. Daniel K, Omache R. Local Public Markets: Critical to Achieving a Sustainable Food System. HealthBridge; 2022.
82. Kafle A, Hopeward J, Myers B. Modelling the Benefits and Impacts of Urban Agriculture: Employment, Economy of Scale and Carbon Dioxide Emissions. *Horticulturae*. 2023;9(1):67.
doi:<https://doi.org/10.3390/horticulturae9010067>
83. Mitchell M, Iglesias AR. Urban agriculture in Kathmandu as a catalyst for the civic inclusion of migrants and the making of a greener city. *Frontiers of Architectural Research*. 2020;9(1):169-190.
doi:<https://doi.org/10.1016/j.foar.2019.07.007>
84. Bauske EM, Westerfield B. Community Gardening Involves Cultivating People.; 2017. Accessed April 3, 2023.
https://secure.caes.uga.edu/extension/publications/files/pdf/B%201399_2.PDF
85. Simmons A. 5 Inspiring Examples of Urban Gardens from Around the World. PopEd Blog. Published July 21, 2017.
<https://populationeducation.org/5-inspiring-examples-of-urban-gardens-from-around-the-world/>
86. World Resources Institute. RELEASE: Prize for Cities Awarded to Rosario, Argentina, for Improving Resilience and Equity Through Urban Agriculture. www.wri.org. Published June 29, 2021. <https://www.wri.org/news/release-prize-cities-awarded-rosario-argentina-improving-resilience-and-equity-through-urban>
87. UNICEF South Africa. Let's get planting - from Salt River to Soweto. Published October 25, 2020.
<https://www.unicef.org/southafrica/stories/lets-get-planting-salt-river-soweto>
88. Javits Centre. Rooftop Habitats - Javits Center. www.javitscenter.com. Published 2019.
<https://www.javitscenter.com/en/sustainability/rooftop-habitats/>
89. C40. Our Cities. C40 Cities. Published 2023. <https://www.c40.org/cities/>
90. Arup International Development. City Resilience Framework. The Rockefeller Foundation. Published December 2015. <https://www.rockefellerfoundation.org/wp-content/uploads/City-Resilience-Framework-2015.pdf>
91. UNEP. State of Finance for Nature 2022 Time to Act: Doubling Investment by 2025 and Eliminating Nature-Negative Finance Flows.; 2022. <https://www.unep.org/resources/report/state-finance-nature-2022>
92. Kong L, Mu X, Hu G, Zhang Z. The application of resilience theory in urban development: a literature review. *Environmental Science and Pollution Research*. 2022;29(33):49651-49671. doi:<https://doi.org/10.1007/s11356-022-20891-x>
93. Lahsen M, Ribot J. Politics of attributing extreme events and disasters to climate change. *WIREs Climate Change*. Published online December 8, 2021. doi:<https://doi.org/10.1002/wcc.750>
94. UN Habitat. CityRAP Tool: City Resilience Action Planning Tool.; 2020.
https://unhabitat.org/sites/default/files/2020/05/cityrap_tool_booklet_2020.pdf
95. UNFCCC. Subsidiary Body for Scientific and Technological Advice.; 2017.
<https://unfccc.int/resource/docs/2017/sbsta/eng/inf03.pdf>

Appendix A: Summary of Strategies Proposed

STRATEGY AND PUBLIC SPACE	BENEFITS	CHALLENGES	CLIMATE RISKS	SDGs
<p>Incorporate greenery in public spaces</p> <p><i>Public spaces:</i></p> 	<p>Greenery can help reduce pollution and UHI effect</p> <p>Can engage community members</p> <p>Improves overall physical and mental health</p> <p>Established programs exist</p> <p>Can apply in all public spaces</p>	<p>Costs can vary</p> <p>Greenery can be harmful if not selected properly (ex. allergies)</p> <p>Can be difficult to maintain</p>		
<p>Build Resilient Roofs</p> <p><i>Public spaces:</i></p> 	<p>Greenery can help reduce pollution and UHI effect</p> <p>Can limit electricity bills</p> <p>Various ways to build resilient roofs (Ex. green or cool roofs)</p> <p>Can apply in various public spaces</p>	<p>Green roofs can be hard to maintain</p>		

<p>Strengthen coastal defenses</p> <p><i>Public spaces:</i></p> 	<p>Can be community led</p> <p>Restoration efforts have good success rates</p> <p>Natural defenses are pre-existing and adaptable</p>	<p>Some restoration (ex. coral restoration) can be costly</p> <p>Could take a long time for forests to regenerate</p>	    	   
<p>Protect Urban Wetlands</p> <p><i>Public Spaces:</i></p> 	<p>Can be community led</p> <p>Can be enjoyed by communities</p> <p>Multiple benefits: reduce GHG, provide habitats for birds and animals, reduce air pollution, improved aesthetics</p> <p>Greenery can help reduce pollution and UHI effect</p> <p>International collaboration to protect wetlands already exists</p>	<p>This could be a large project, making it costly.</p> <p>Improperly managed wetlands could spread diseases and emit GHG</p>	    	    

<p>Invest in BGI</p> <p><i>Public spaces:</i></p> 	<p>Combines NBS and traditional models of construction, offering multiplied benefits</p> <p>Greenery can help reduce pollution and UHI effect</p> <p>Can be incorporated in many public spaces</p>	<p>Could be costly</p> <p>Might require maintenance, which can add further costs</p> <p>Can contradict existing building codes</p>		
<p>Incorporate stormwater management system in public infrastructure</p> <p><i>Public spaces:</i></p> 	<p>Models and strategies already exist (Ex. LID)</p> <p>Can be incorporated in many public spaces</p>	<p>Some structures can be costly to build</p>		

<p>Build Resilient Markets</p> <p><i>Public spaces:</i></p> 	<p>Can be community led</p> <p>Can range from small to large projects</p> <p>Can be sustainable</p> <p>Help reduce GHG emissions</p> <p>Greenery can help reduce pollution and UHI effect</p> <p>Social benefits such as employment, reduced food insecurity etc.</p> <p>Can be incorporated in many public spaces</p>	<p>Can be challenging getting started: money, expertise etc.</p> <p>Large scale operations can require lots of money</p>		
--	--	--	---	---

Appendix B: List of General Resources

- Conexus is a project which pools together relevant knowledge related to NBS in Europe and Latin America. The “[case study](#)” section of the website consists of various examples of NBS implemented throughout Europe and Latin America.(46)
- The C40 network comprises of almost a 100 cities worldwide, who have united to combat the climate crisis in cities. [Participating cities and the measures](#) they have taken are featured on this website, which can be beneficial to gain ideas. (89)
- [Rockefeller Foundation’s Framework on City Resilience](#). This document defines resilience in cities and provides a framework on building a resilient city and can be beneficial in trying to understand what makes a resilient city. It also consists of case studies which particularly highlight the value of NBS and community engagement. (90)
- [UN Habitat’s City Resiliency Planning tool](#) which provides a step-by-step guide on how to build resilience in a city. This guide is more applicable to policy makers and government. However, it contains information on how to educate people on urban resilience and how to identify risks faced by cities. (94)
- UNFCC’s report on a [Summary of Global Initiatives on Climate Adaptation and Resilience](#). This resource is particularly helpful for those seeking to join an established organization and their initiatives. (95)