

UNLOCKING THE POTENTIAL FOR TRANSFORMATIVE CLIMATE ADAPTATION IN CITIES

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EXECUTIVE SUMMARY

Highlights

- Cities are increasingly integrating climate adaptation priorities into development policies and plans. However, there remains a gap in understanding how incremental urban adaptation solutions can lead to more transformative change over the long term.
- Transformative adaptation reorients urban climate actions around addressing entrenched equity and climate justice challenges. It focuses on systemic changes to development processes that improve people’s quality of life, enhance the social and economic vibrancy of cities, and ensure sustainable, resilient, and inclusive urban futures.
- This paper systematically reviews literature and case studies across the global North and South to assess the barriers and enablers to transformative climate adaptation, focusing on examples and evidence from a wide range of cities.

About this paper

This paper is part of a series of background papers commissioned by the Global Commission on Adaptation to inform its 2019 flagship report. This paper reflects the views of the authors, and not necessarily those of the Global Commission on Adaptation.

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- We highlight three key action areas that cities can focus on to help advance transformative urban adaptation: mainstreaming information on climate risks in the spatial planning and delivery of urban services; partnering with vulnerable and informal groups to build their resilience; and using nature-based solutions to respond to water, heat, and other risks.
- Adequate resources for infrastructure and service delivery, strong leadership, accountable institutions, and data-driven metrics co-created with communities can help cities prioritize climate adaptation solutions. Partnerships across public, private, and civil society actors can build support for adaptation priorities, which must be implemented in conjunction with climate mitigation, ecosystem protection, economic growth, and sustainable development objectives at the local level.

The Challenge: Cities and Vulnerable Populations at Grave Risk

Home to over half of the world's population and producing more than 80 percent of global GDP, cities¹ face grave risks from sea level rise, flooding, heat and water stress, degradation of urban ecosystems, loss of biodiversity, and other climate change impacts.² Sea level rise and storm surges alone could cost coastal cities US\$1 trillion each year by midcentury, affecting more than 800 million people.³ Urban areas in drylands, which host over 2 billion people, face increased water stress and frequent droughts that exacerbate health and food insecurity.⁴ These impacts not only threaten urban economic assets and people's livelihoods, but also the social networks that foster resilience and quality of life, especially for those living in poverty.

By 2050, two-thirds of the world's population will live in urban areas,⁵ with the most rapid growth occurring in underresourced cities in the global South that have large vulnerable populations and low capacity to adapt to climate change.⁶ Many of these cities have growing informal settlements, home to over 880 million residents globally,⁷ with limited access to secure shelter, electricity, clean water, sanitation, and employment opportunities. Climate impacts are likely to worsen access to such services, especially for vulnerable populations, including women and girls, children and the elderly, migrants, indigenous populations, and minorities.

Urban development that is blind to climate risks is increasing exposure to climate hazards in cities. Natural protections like floodplains, wetlands, and biodiversity zones within and around cities have been lost, and natural drainage areas have been built over.⁸

As cities have grown, rampant and often unregulated construction in at-risk areas is compounding flooding damage and temperature-related losses to the environment, human health, and productivity. Climate change is also increasing the damage from extreme events to critical urban infrastructure like rail and road systems, bridges, electricity grids, and water supply lines.

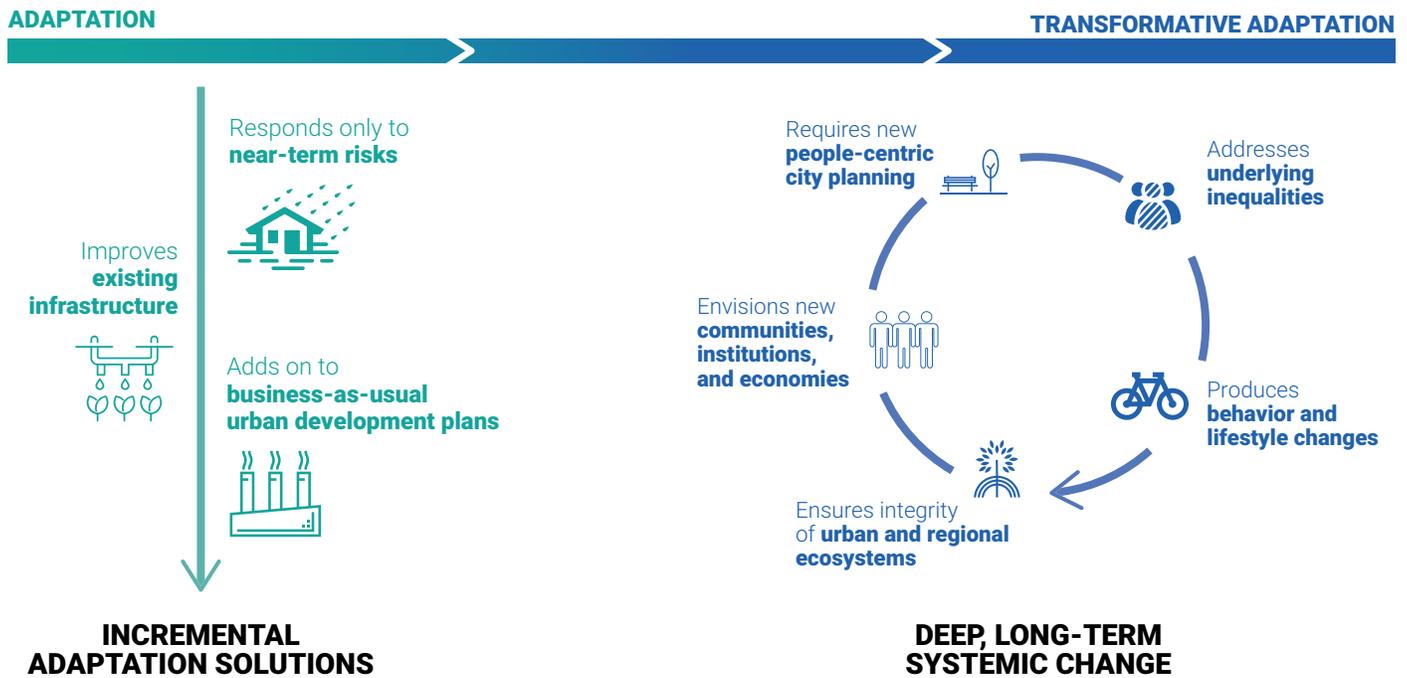
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The Way Forward: Building Resilient and More Equitable Cities

Cities need transformative approaches to deal with climate change (see Figure ES-1). The IPCC 1.5°C Special Report identifies cities as a critical global system to “accelerate and upscale climate action.”⁹ Cities must adapt to climate change in a way that corrects underlying inequalities, while remaining centers of opportunity for people and economic powerhouses for nations. This requires new types of institutions, communities, built environments, and production and consumption systems that help ensure the integrity of urban and regional ecosystems.¹⁰

Such transformative adaptation approaches require action at all levels, from grassroots community groups and private actors to city planning departments, and regional and national agencies. Done carefully, through mobilizing resources, harnessing synergies between climate



Source: Author’s synthesis, adapted from Bazaz et al. 2018.¹¹

adaptation and mitigation, and simultaneously tackling persistent problems like poverty, inequality, and basic infrastructure deficits, adaptation efforts can put cities on a stronger, safer path that offers economic opportunities and higher quality of life for all.

Three Action Areas to Make Cities More Climate-Resilient and Inclusive

1. MAINSTREAM INFORMATION ON CLIMATE RISKS INTO SPATIAL PLANNING AND THE DELIVERY OF URBAN INFRASTRUCTURE AND SERVICES, WHILE STRENGTHENING LOCAL CAPACITY

Knowledge providers and local, national, and global actors should make the latest modeling technologies and credible data on climate risks available to cities and communities. Many cities in the developing world currently lack even basic floodplain maps that are crucial to adaptation efforts. All cities urgently need updated

topographic and elevation maps, along with weather and climate information, satellite, and remote sensing data; models that reveal risks of climate impacts to local areas; and assessments of the vulnerabilities for specific population groups, such as women and people living in poverty. Importantly, cities should build capacity to use this information for decision-making. Collaborations among local research institutions, civil society, community groups, the private sector, and city governments are essential to address gaps in information and capacity, and can create efficiencies with high returns on investment.

City decision-makers should build capacity to use this information in a transparent and inclusive manner to drive integrated urban planning, investments, and operations to reduce climate risks. Cities can select less hazard-prone locations for infrastructure, improve standards to which infrastructure must be built, better understand accelerated asset depreciation due to climate change, and respond more efficiently when disasters occur. Surat, India, for instance, relocated key industry clusters

away from flood-prone zones and created an early warning system for flooding.¹² These planning and decision-making processes must prioritize the needs of the most vulnerable.

City decision-makers should construct new buildings and infrastructure to withstand projected climate impacts and must retrofit existing infrastructure and services.

Protecting built assets from extreme storms, flooding, and heat will reduce maintenance costs, safeguard users and tenants, and increase building and infrastructure lifetimes. Disaster preparedness and response systems must be made an essential part of designs and operations. Examples include elevating docks and wharfs at ports based on flood risks; increasing flood protection and water pumping capacity at underground public transit stations and tunnels; building potential redundancies into service delivery systems as part of disaster response; using corrosion-resistant materials for roads, bridges, and utility networks; and designing open space to soak up more stormwater. All these actions typically require more resources, and too many city governments have very limited investment and technical capacity. None of these steps are easy, but they offer major payoffs in future losses avoided, greater economic returns, lower infrastructure maintenance costs, and longer building and infrastructure lifetimes. In coastal cities, for instance, the annual cost of global adaptation is one-tenth the total cost of no action.¹³ Adaptation action in cities can even mitigate climate change. Better public transit infrastructure can both improve resilience and cut carbon emissions, for example, and make it possible to connect low-income urban dwellers—who increasingly live in women-headed and minority households—to better jobs.

City decision-makers need to coordinate within city agencies and across sectors and scales of government to mainstream climate adaptation across planning and infrastructure delivery.

Integrated, cross-sectoral approaches are the best way to enhance resilience in cities. For example, against a backdrop of decreasing water availability and rising unpredictability in many cities, integrated planning of water use across residential, industrial, energy, agricultural, and other sectors is essential. Higher levels of government can incentivize such collaboration as a condition for cities to receive financing. Decision-making processes should bring together formal and informal institutions and include vertical collaboration across national, regional, and local governments. The

Surat Climate Change Trust in Surat, India, for example, was born out of the realization that more than a dozen different agencies and institutions had a share of the overall flood-management responsibility for the city—and that successful adaptation required city officials, natural resource authorities, and state disaster management authorities to work together.¹⁴

2. BUILD CLIMATE RESILIENCE BY UPGRADING LIVING CONDITIONS IN VULNERABLE COMMUNITIES AND INFORMAL SETTLEMENTS, DRAWING UPON LOCAL EXPERIENCE AND COMMUNITY KNOWLEDGE

City governments must strengthen the adaptive capacity of vulnerable and informal communities.¹⁵

Climate risks and resource scarcities disproportionately affect the poor and most vulnerable, many of whom live in underserved informal settlements. These communities are often at risk from flooding or landslides,¹⁶ are susceptible to extreme heat, and have little or no political voice in cities. Government and community-led schemes to upgrade informal settlements involve installing infrastructure for improved housing, water, sanitation, drainage, waste management, and thermal comfort. This lowers the disease burden on poor households, increases the productivity of informal workers, and improves health outcomes with lasting benefits for communities and cities, while building resilience. For instance, the Asian Coalition for Community Action (ACCA) program had supported community-led upgrading across over 2,000 communities in 207 cities in 18 countries by 2014.¹⁷ However, the huge deficits in basic infrastructure in many cities require significant investment in climate-resilient trunk infrastructure (water mains, sewerage lines, electricity grids) that community-led upgrading efforts can then connect to, and many city governments lack this investment capacity. National government and external funding can support such partnerships between city governments and informal communities, as seen in numerous cities across Africa and Asia.

City decision-makers must tap into citizen knowledge and experience, especially from marginalized communities, to support more inclusive climate adaptation strategies. To redress development inequalities and support poverty reduction, adaptation must address

head-on the issues of power and economic, social, and political marginalization in urban areas. Because accurate information on informal settlements and climate impacts is often lacking, many actions, when taken, are ineffective or make things worse. Cities thus must do more to engage vulnerable communities in improving resilience, as in the “Know Your City” Initiative, where residents of informal settlements in over a 100 cities help gather data to understand climate risks and prioritize upgrading investments.¹⁸

3. PRIORITIZE NATURE-BASED SOLUTIONS TO HOLISTICALLY MANAGE WATER AND HEAT RISKS

Cities, regional agencies, and water utilities must adopt integrated approaches that together address flood and heat management, and protection of water sources.

Cities face increasing uncertainties in the availability of water. They face growing challenges of water scarcity and excess, and droughts due to extreme temperatures, from the water crisis in Cape Town, South Africa, to heat waves in European cities. Managing water more holistically can help cities protect natural water sources and channels, track water consumption and stormwater runoff, and utilize water reservoirs to create zones of comfort from heat. Green roofs and greater tree cover can cool cities and reduce energy use, and wetlands and forests can temper floods and increase water supplies by protecting water sources. In many cases, these and other nature-based solutions are remarkably cost-effective: In São Paulo, for instance, the reduction of sediment flow from restoring 4,000 hectares of forests near the city’s watershed was estimated to be \$4.5 million cheaper than the cost of dredging reservoirs to improve urban water quality.¹⁹ Such steps must be implemented carefully, however, to prevent inequities and “green gentrification.”²⁰

City decision-makers must coordinate nature-based solutions across jurisdictions and with regional agencies, since ecosystems such as watersheds typically extend well beyond urban boundaries. The city of Durban, South Africa, helped establish a transboundary partnership to address water security problems across the broader uMngeni River catchment, while also improving water and sanitation access for impoverished and peri-urban areas and experimenting with graywater reuse techniques.²¹

Enablers of Transformative Adaptation in Cities

The above strategies cannot be considered mutually exclusive; they must be integrated with each other and require common enabling conditions (see Table ES-1). Given the diversity across cities, implementation of the above recommendations must respond to different levels of technical and financial capacity and varying institutional structures in cities.

Conclusion

Climate change poses systemic risks to cities and the vulnerable populations and ecosystems within them. Transformative strategies are needed to integrate adaptation into cross-sectoral development objectives (see Figure ES-2). These strategies should address long-term equity concerns in urban planning, infrastructure development, and decision-making, as well as emerging adaptation solutions. An increasing number of cities are recognizing diverse urban interests, the need to include marginalized and vulnerable populations in decision-making, and to fairly distribute the costs and benefits of climate adaptation actions.²² However, creating an urban future that is more inclusive, sustainable, and resilient will require a transformative vision and a reorientation toward justice and rights-based frameworks that can drive large-scale, long term, and qualitative change.²³

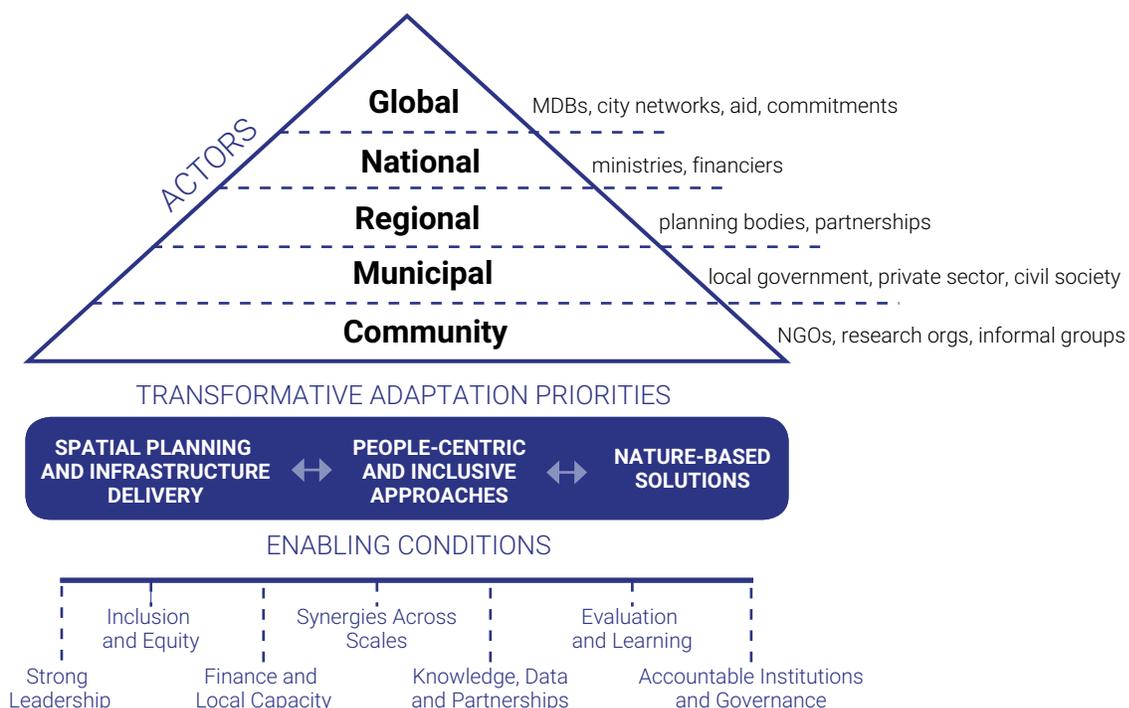
ENABLING CONDITIONS	RECOMMENDATIONS TO MAKE PROGRESS	TIME SCALES
Strong leadership	• Nurture political leaders, knowledge entrepreneurs, and social movements that can raise awareness and advocate for climate adaptation.	Short/Medium
	• Reframe current and future urban development trajectories through the “climate lens,” taking into account recent scientific projections and the need for more innovative and inclusive visions of urban futures.	Medium/Long
	• Promote transformative resilience thinking in decision-making and planning.	Medium/Long
Inclusion and equity	• Prioritize engagement with urban poor, vulnerable, and marginalized stakeholders in climate adaptation planning.	Short
	• Design participatory arenas to ensure the coproduction of adaptation solutions between public, private, community-based, informal actors, as well as international experts.	Short/Medium
	• Ensure strong community ownership and buy-in to adaptation interventions and resilient development outcomes.	Short/Medium
	• Devise parameters to ensure procedural and distributive inclusiveness, social equity, and climate justice.	Medium/Long
Finance and local capacity	• Step up financial support for urban adaptation, and ensure international financial institutions, donors, and the private sector prioritize valuing and incentivizing such investments.	Short
	• Harness and share the value created from adaptation investments between local governments and private actors, ensuring equitable distribution of benefits across population groups.	Short
	• Create funding incentives or commit resources for local engagement and demonstration projects with cross-agency coordination at city level. Design intergovernmental funds that support adaptation planning and action.	Short
	• Address and analyze capacity and skills gaps in the context of climate adaptation, risk management, and resilient development at the local level.	Short
	• Recognize the “resilience dividend” in the design, prioritization, and implementation of both “soft” and “hard/engineered” adaptation actions. Increase climate-resilient investments and capture value from adaptation benefits.	Short/Medium
	• Revisit regulatory frameworks to allow for more effective pooling and steering of public, private, and community-based sources of adaptation finance.	Short/Medium
	• Provide training and institutional support to municipal authorities to prevent outsourcing of adaptation planning and to better reflect local priorities.	Short/Medium
	• Delineate financial logic and investment criteria for socially responsible, sustainable, and equitable forms of infrastructure and service delivery.	Short/Medium
	Synergies across regional, national, and global scales	• Facilitate more comprehensive adaptation strategies by harnessing networks and partnerships with transnational actors, rural districts, nongovernmental organizations (NGOs), and transboundary institutions.
• Ensure that regional and local adaptation plans build upon major national policies and commitments, particularly in the context of urbanization trajectories; other subnational climate strategies; economic development plans; land use and transportation plans; critical infrastructure policies; and strategic, fiscal, and investment plans.		Short
• Support global scientific assessments and toolkits that include city-level knowledge and experiences.		Short
• Embed and synchronize adaptation planning within national, regional, and international resource distribution, regulations, and financing strategies through incentives and guidance.		Short/Medium
• Offer incentives for sharing knowledge, capacity, and resources across city networks, focusing on South-South collaborations, in particular.		Short/Medium

TABLE ES-1

Key Recommendations for Transformative Adaptation Action in Cities (with time scales)

ENABLING CONDITIONS	RECOMMENDATIONS TO MAKE PROGRESS	TIME SCALES
Knowledge, data, and partnerships	• Require and support cross-agency and cross-sectoral knowledge exchange and consultation on urban climate adaptation and resilient development.	Short
	• Foster data and knowledge co-production platforms between city government, civil society and community groups, and research and academic institutions to make climate science and possible adaptation pathways specific to the needs of local decision-makers and users.	Short/Medium
	• Enable multiscalar partnerships, mechanisms for resource transfer, and knowledge communities between cities and global, national, regional, and community-level institutions.	Short/Medium
	• Support long-term science-policy-practitioner coordination with effective citizen communication strategies.	Medium/Long
Evaluation and learning	• Devise and apply inclusive monitoring, assessment, and evaluation metrics for cobeneficial urban adaptation actions.	Short/Medium
	• Facilitate South-North and South-South models of peer learning and evaluation of urban adaptation actions.	Medium
	• Create a global open access repository of data at the city level capturing climatic and socioeconomic variables, thereby generating lessons that can be replicated across scales.	Medium
Accountable institutions and governance	• Ensure and encourage planning for urban adaptation at the national level because many cities depend heavily on national transfers and policies.	Short
	• Break the silos of urban governance and management to incentivize more holistic and multi-jurisdictional spatial planning and policymaking around climate adaptation.	Short
	• Promote autonomy and flexibility in local government policymaking to support more innovative forms of adaptation action.	Short/Medium
	• Develop robust institutional mechanisms to manage potential economic losses and navigate tensions and conflicts in climate adaptation.	Medium
	• Develop governance accountability frameworks to ensure transparency, equity, and inclusivity in climate adaptation.	Medium

Source: Authors' synthesis.



Note: See Table ES-1 above for detailed recommendations on Enabling Conditions.

Source: Authors' synthesis.

1. THE CHALLENGE OF URBAN CLIMATE ADAPTATION

By 2050, two-thirds of the world's population is projected to live in urban areas, presenting an immense challenge for decision-makers and residents alike. Globally, rapid urban growth already poses urgent challenges, including inadequate infrastructure, rising social inequality, and entrenched poverty. Climate change is exacerbating those challenges.²⁴ This section introduces the emerging opportunities and constraints surrounding adaptation in cities and explains why cities and city-regions are suitable contexts for innovative and systemic intervention. It synthesizes insights from recent scientific findings and policy developments, which call for developing new methodologies to account for the benefits, costs, and

synergies of adaptation, while recognizing the systemic, multiscalar, and interregional drivers of climate risks and vulnerabilities. The section then broadens awareness of the potential resource, capacity, and knowledge pathways for scaling up adaptation interventions. Finally, it outlines emerging knowledge gaps and describes the structure of the paper.

1.1. The Urgency of Transformative Climate Adaptation in Cities

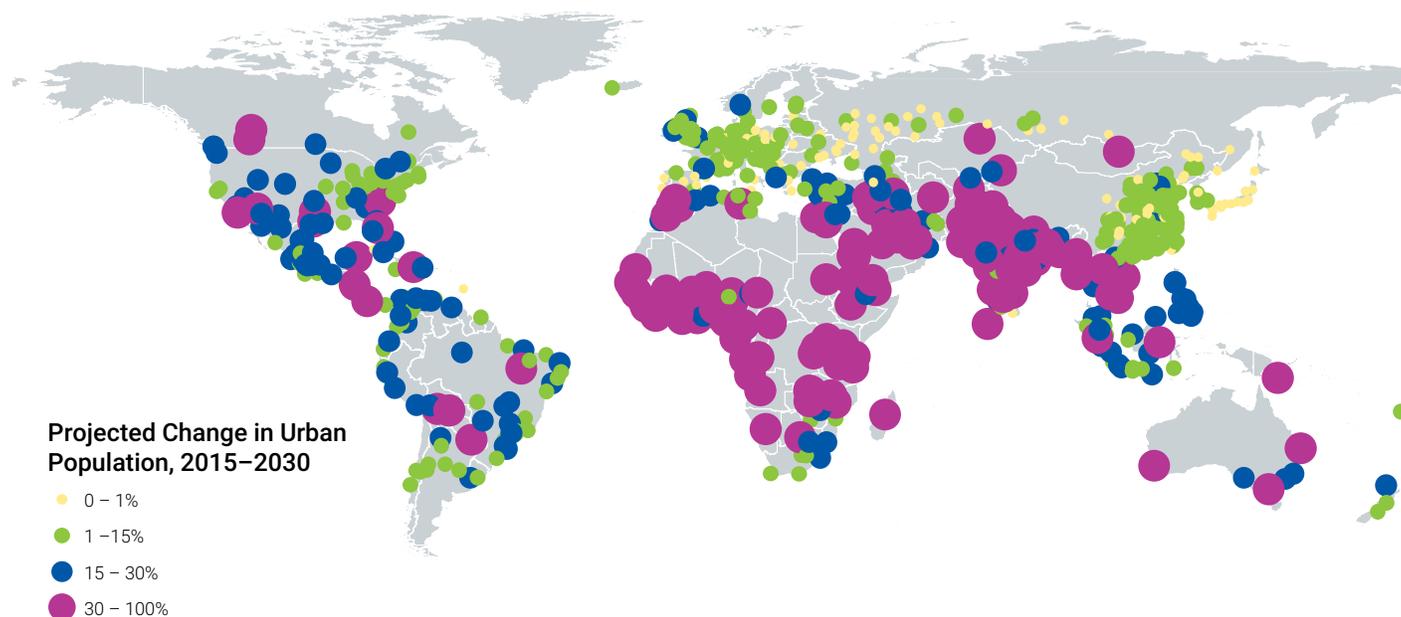
Urgent climate adaptation action is needed in cities because cities concentrate critical assets such as infrastructure, manufacturing, financial services, knowledge, and the capacity for innovation. These assets are increasingly exposed to both extreme and slow-onset climate change impacts (see Section 2.1 for details). The

half of the world's population that currently lives in cities produces more than 80 percent of global GDP, and just 380 of the world's largest cities account for half of global GDP.²⁵ Sub-Saharan Africa now produces the smallest share of global urban GDP. The largest share comes from East Asia. Over the next 10 years, the McKinsey Global Institute's Cityscope 1.0 model anticipates that cities will generate 75 percent of global economic growth. It predicts that cities smaller than 10 million people will deliver more growth than all the megacities in the global North and South combined.²⁶ Between 2015 and 2030, cities with populations between 1 million and 5 million will experience the fastest economic growth.²⁷ Massive numbers of people will flock to cities in the Global South. In the next three decades, the urban population is expected to surge by 2.5 billion, and 90 percent of that growth will likely take place in emerging cities in Asia and Africa.²⁸ The fastest-growing cities will be in Sub-Saharan Africa and South Asia—places

with the fewest resources per capita to deal with the challenges of rapid urban growth.²⁹ Figure 1 illustrates how urbanization pressures are particularly acute across the global South.

On top of rapid population growth, cities in the global South face the pressures of coping with poverty, unregulated settlement, informality, and rising inequality. The areas under greatest economic stress are also those most vulnerable to the impacts of climate change. Degraded and inhospitable urban lands—such as floodplains, steep slopes, and areas near dumps and other environmental hotspots—often house a city's poor, underrepresented, and marginalized populations. In coastal areas and riparian zones, the poor are also concentrated in hazardous places such as floodplains or neighborhoods surrounding toxic waste facilities.³¹ Even though more affluent populations also inhabit high-risk zones (such as high-income seafront

FIGURE 1 Growth Rates of Urban Agglomerations by Population Size, 2015–2030



Source: Beard, Mahendra, Westphal, 2016, based on data from Oxford Economics, 2016³⁰

properties), those privileged groups have greater access to resources important for adapting to and coping with shock and stress events.³²

City budget per capita is an indicator of both a city’s available financial resources and its capacity to cope with climate challenges. Figure 2 compares municipal budgets across 30 cities, illustrating the stark contrast between cities in more developed countries and those in Asia and Africa that have only a fraction as much to spend.

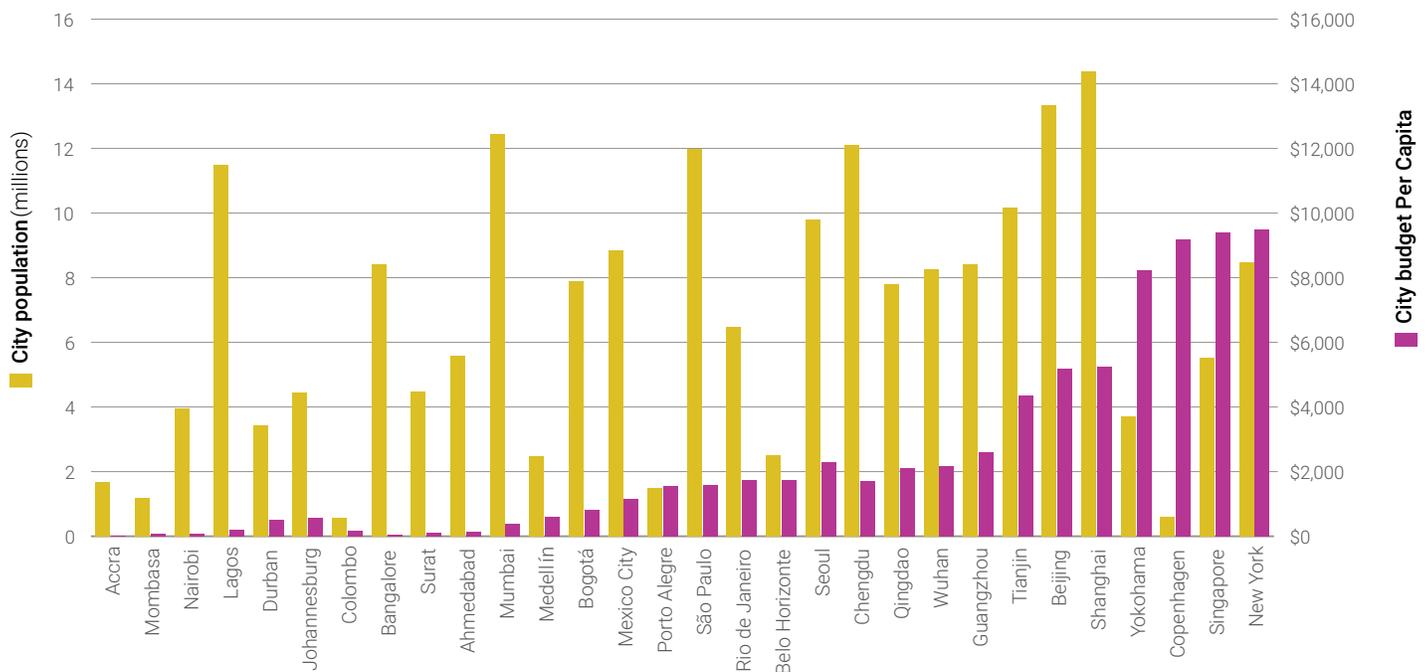
Resources pose just one challenge. Because climate change has the potential to worsen social and economic inequalities, cities urgently need comprehensive adaptation strategies. Whereas an incremental approach concentrates on immediate risks and development needs, a more comprehensive—or transformative—approach reaches further, seeking to rectify underlying inequalities and

injustices while envisioning new types of communities, socioeconomic pathways, and built environments.³⁴ A transformative vision for urban adaptation therefore entails more innovative, sustainable, and resilient lifestyles; human settlements; and economic production systems, while bringing about a reorientation toward justice and rights-based frameworks for decision-making and policymaking (see Figure 3).

1.2. Insights from Recent Climate Assessments

Global scientific assessments—including the recently published Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C of Global Warming³⁶ and the Cities IPCC agenda³⁷—point to urban areas as centers and drivers of more transformative climate change action. The report identifies cities as a critical global system

FIGURE 2 Municipal Budgets per Capita and Population across Cities



Source: Beard, Mahendra, and Westphal, 2016.³³

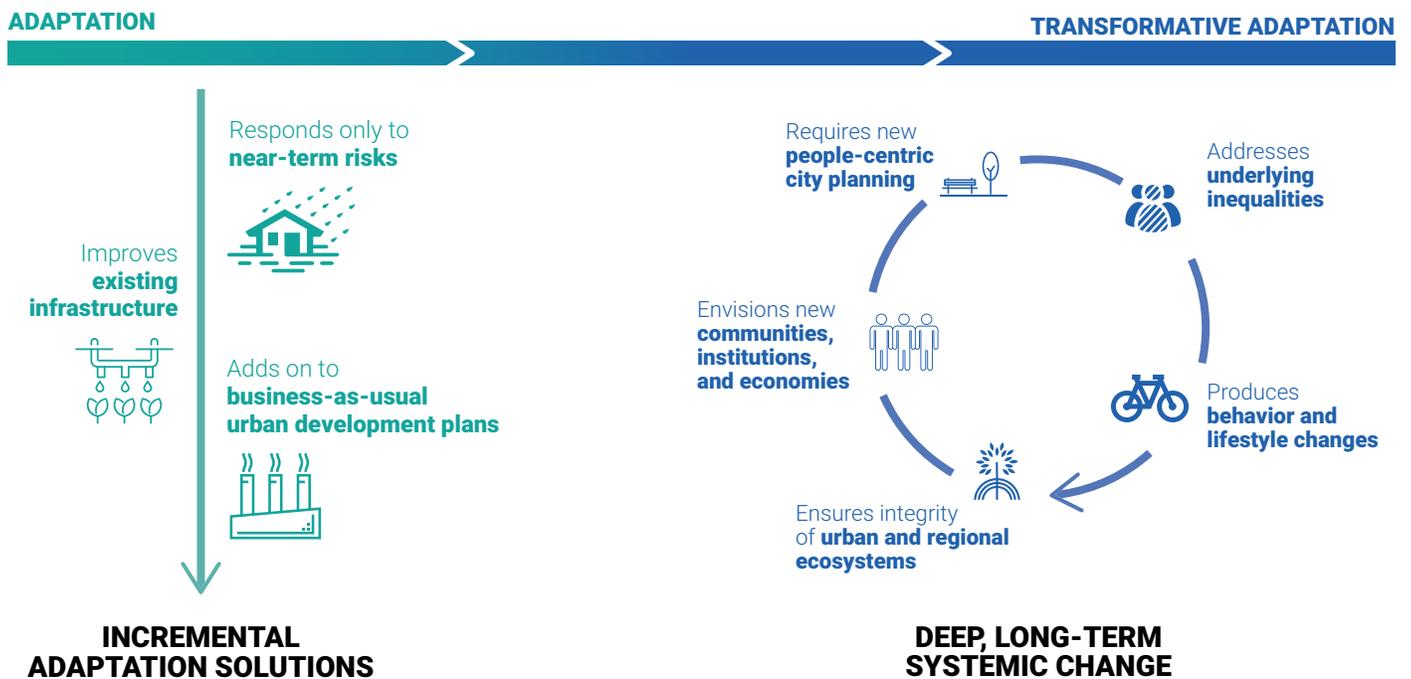
Note: Budget data represent years 2010 to 2016. Cities are ordered on x-axis in increasing order of city budget per capita.

to “accelerate and upscale climate action.” Cities must adapt to climate change in a way that corrects underlying inequalities, while remaining centers of opportunity for people. This requires new types of institutions, communities, and built environments, and production and consumption systems that help ensure the integrity of urban and regional ecosystems.

While global climate models and projections are increasingly becoming more robust, predicting local impacts on cities and particular neighborhoods within them remains a challenge. Scientific uncertainty shrouds questions of how multiple impacts mapped against time will interact with or compound each other, or how climatic shifts will permeate local social, political, and economic conditions. Consequently, it is imperative to assess how climate change might influence land, air,

and water systems, and how these risks might affect urban infrastructure, assets, and people. Those who rely on downscaled climate projections need better tools for anticipating needs. Recent scientific assessments note the need for a clearer picture of what will happen to residential and commercial buildings, roads, utilities, communication networks, hospitals, schools, industrial and manufacturing sites, and environmental hotspots (including waste sites, brownfields, etc.). It is also vital to collect and disaggregate demographic data on the socioeconomic and health status of vulnerable groups such as informal residents and workers, female-headed households, the elderly, youth, people with disabilities, and others. For smaller cities and towns in the global South—surging in both population and size—visualizing future urban growth can also inform discourse on how to identify and prioritize adaptation measures and allocate scarce resources.

FIGURE 3 Incremental vs. Transformative Urban Adaptation to Climate Change



Source: Authors' synthesis, adapted from Bazaz et al. 2018.³⁵



Photo Credit: Aji Jayachandran.

Cities are important sites for climate finance, technology, and policy innovation. This has been noted in recent global assessments by the Intergovernmental Panel on Climate Change (IPCC), World Resources Institute (WRI), World Bank, UN-Habitat, and others. Cities are also emerging arenas of experimentation and citizen participation, where diverse stakeholder groups are taking action and engaging in local climate action planning to achieve mitigation and adaptation goals.³⁸ Over the past decade, numerous studies have documented the emergence of urban “early adopters” of adaptation.³⁹ They note that robust scientific projections, strong municipal leadership, and relevance to ongoing planning and development agendas are key drivers of adaptation action across the global North and South.⁴⁰ Other studies have also pointed to cities as nodes of political awareness and arenas of participatory action, especially in places where knowledge, resources, and capacity are limited.⁴¹ However cities pursuing climate adaptation and resilience priorities face hurdles and constraints. These include limited finances and bureaucratic capacity; weak local authority; competing development priorities; and political pressure to focus on immediate, rather than long-term, goals.

Transformative adaptation focuses on systemic changes to development processes that improve people’s quality of life; enhance the social and economic vibrancy of cities; and ensure sustainable, resilient, and inclusive urban futures. It also reorients urban climate actions around addressing entrenched equity and climate justice challenges. Recent assessments (see Box 1) call attention to principles of justice as integral to developing a more transformative vision of adaptation and informing cities’ responses to climate change.⁴² Justice is central, given the inequitable impacts of climate change on the poor, women, children, the elderly, and ethnic/class minorities.⁴³ This is highlighted in the New Urban Agenda agreed at UN-Habitat III, which envisions cities that address pervasive marginalization and cater to all groups’ needs. Examining adaptation through a justice lens allows us to unpack the social, economic, and political differences that can influence how disparate groups are exposed to and affected by climate change. This approach also speaks to the variable costs and benefits associated with adaptation actions, particularly for marginalized groups such as migrants, informal settlement dwellers, and other urban poor populations. Mainstreaming justice in urban

adaptation emphasizes the need for a people-oriented vision. It asks the questions, *for whom, through what mechanism, and to what end*.⁴⁴ This means engaging; giving due recognition; distributing risks, costs, and benefits fairly; and adopting procedures to achieve parity of participation, improved equity outcomes, and the long-term stability of the adaptation program (see Section 3.2).⁴⁵

1.3. Knowledge Gaps

To help answer these questions, this comprehensive study assesses the potential for transformative adaptation action in cities, examining contextual requirements, enabling conditions, policy constraints, and sources of resource and capacity support. It asks the following questions:

1. What innovations can make it easier to cope with local, often uncertain, climate change risk and impacts, and how will political, social, economic, and cultural conditions shape adaptation strategies and implementation?
2. What institutional and governance mechanisms are necessary for designing, implementing, and evaluating adaptation actions at scale.
3. Which concrete examples of successful—or even transformative—climate adaptation in cities can provide a model for others?

This paper builds upon the recent Cities IPCC Research Agenda (2018) that identified key urban-related priorities for the Sixth Assessment cycle of the Intergovernmental Panel on Climate Change (2018–2022) (see Box 1). It takes a critical and comparative look at common weaknesses and gaps in existing approaches to urban adaptation and explores ways to empower local governments and urban residents to pursue more equitable and transformative strategies. We highlight the essential role of cities as centers of innovation; the need for collaboration; and the importance of integrating climate adaptation with economic development, social protection, infrastructure/asset investment, land management, ecosystem preservation, and other priorities.

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seeks to accelerate adaptation action and support by elevating the political visibility of adaptation and focusing on concrete solutions. It is convened by 17 countries and guided by 30 Commissioners, and comanaged by the Global Center on Adaptation and the World Resources Institute. This paper reflects the views of the authors, and not necessarily those of the Global Commission on Adaptation.

1.4. Barriers to Transformative Climate Adaptation

Climate adaptation priorities have yet to be fully or systematically incorporated into the wider urban planning and development agenda.⁴⁷ Cities are sometimes hobbled by institutional fragmentation, scarce finances, limited autonomy from national governments, and contending environmental and development goals.⁴⁸ For many cities, adaptation planning encapsulates both “traditional” development goals (providing public services, maintaining economic competitiveness) and emerging climate-related development goals (reducing risk, ensuring safety and well-being, and confronting policies that generate more vulnerability).⁴⁹ Adaptation priorities can be complicated by a rapidly shifting demography, burgeoning informal economies, political patronage and corruption, privatization of basic services, and the lack of expertise in municipal administrations. These challenges are particularly profound for secondary cities in the global South whose growth is outstripping their capacity to effectively meet needs.⁵⁰ Table 1 provides a selection of barriers to adaptation action in cities across the global North and South.

Many cities cite governance, finance, skills, and capacity constraints as the primary barriers to adaptation action.⁵¹ Fine-grained, localized climate projections and scenarios may be unavailable, inhibiting steps to integrate adaptation priorities into long-term land management, infrastructure development, and asset protection programs. Recent improvements in the resolution of downscaled climate projections are sharpening understanding of how different events or impacts will likely unfold. Still, in the urban context, vulnerability and risk stem not only from direct climate impacts, but from a multitude of socioeconomic and cultural conditions that should be better understood and represented. Spatial planning, economic growth, and community development may all be affected. Governments

The Global Research and Action Agenda on Cities and Climate Change Science (2018) highlights a number of key action agendas for cities.⁴⁶ This agenda was drafted in anticipation of the Sixth Assessment cycle of the IPCC (2018–2022), with the view to highlighting cities as sites of experience and knowledge that can inform global scientific assessments. A summary of those agendas relevant for urban climate adaptation is listed here:

Sustainable consumption and production: Understand how the urban and regional economy affects modes, patterns, and chains of production and consumption, and their long-term effects across regional, national, and global scales. Develop pathways for social change that enable urban populations to alter their consumption behaviors in ways that are less resource intensive.

Finance: Develop frameworks and tools to systematically integrate climate considerations into cities' fiscal and financial decision-making, including the full social and economic value of adaptation investments. Explore how public budgets can be strategically used, and can attract private investment to raise the funding needed to invest in economically viable and resilient urban infrastructure. Include low-income and other marginalized urban residents in fiscal and financial decision-making.

Informality: Gain insight into the extent and nature of challenges and opportunities of the informal sector. Inform policy interventions on informality that respond to climate change and recognize the interdependence between the formal and informal economy. Investigate ways to increase adaptive capacity and productivity of the informal sector (including informal housing, residents, workers, and businesses) and scale up solutions from and for the informal sector.

Uncertainty: Evaluate whether existing models are fit for purpose and provide guidelines for simplified approaches to help cities gauge climate change projections and associated uncertainties. Develop tools and methodologies to strengthen decision-making, build confidence, and identify sources of uncertainty.

Urban planning and design: Develop more rigorous analysis of the connections between urban planning, design, infrastructure development, and climate action. Understand the continuum between urban, peri-urban, and natural areas, and the dependencies across them, to better assess cobenefits, synergies, trade-offs, and spillover effects of planning decisions.

Built and natural infrastructure: Explore infrastructure options beyond traditionally dominant gray infrastructure to promote transformational climate solutions in developed and rapidly developing urban areas. Identify the cobenefits of natural infrastructure and ecosystem-based adaptation, and support decision-making about future infrastructure priorities.

TABLE 1

A Selection of Key Structural Barriers/Constraints to Adaptation in Cities

KEY BARRIER	DESCRIPTION
Data, knowledge, and awareness gap	There is often a lack of robust downscaled climate models and datasets that are suitable, applicable, and accessible for local decision-making. Scientists often take a technocratic approach. Policymakers take a political or bureaucratic perspective, while urban residents may rely on personal experiences of climate or weather impacts. Even if data are available, cities lack technical capacity to apply them in decision-making.
Lack of effective leadership, compounded by incomplete or competing planning and policy mandates	This can include the absence of strong political mandates and conflicting departmental development agendas. Many cities also do not have adequate planning and technical capacity for acting upon climate data and models. Economic priorities, bureaucratic staffing, cultures, and mandates, and resource consumption patterns may thwart environmental protection.
High levels of social and economic inequality	This encompasses socioeconomic differences, disparate access to public services, gaps in skills and attainment, as well as outright discrimination and prejudice. Inequalities can be both intentional or an outcome of unjust political and economic processes. Potential implications include being excluded from adaptation decision-making and distribution of adaptation resources, information, and support.
Spatial and scalar mismatch in authority	Political jurisdictions often do not correspond to ecosystem boundaries. The location, scale, and scope of challenges can make them difficult to manage for those confronting them. They may lack authority or responsibility because of how power is divided and distributed between national/regional and local governments or between municipalities and traditional power systems.
Diminishing public sector prerogatives due to lack of accountability	Adaptation can be further constrained by diminishing confidence in the public sector. Worries over corruption and calls for democratization can curtail local governments' power to act. So can ideologies and rhetoric shift away from collective welfare and toward purely market-oriented strategies, private gains, and personal liberties.
Lack of adequate financial resources, local capacity, and skill sets	To change mindsets and practices, adaptation actions require expertise around climate science, infrastructure planning, communication, social science and community engagement, and monitoring and evaluation. Many cities, especially secondary ones, lack the required expertise, skill sets, as well as the associated financial resources and technical capacities to support comprehensive adaptation actions.

Source: Authors' synthesis.

and urban institutions need to be able to deal with uncertainty and advocate for adaptation strategies that stand the best chance of succeeding.

The public's fluctuating interest in climate change is well documented,⁵² and poses another hurdle. Various communication strategies have been deployed to focus people's attention on the risks and increase their willingness to accept or manage trade-offs.⁵³ Some climate change messaging has been criticized for veering away from the truth by downplaying risks or exaggerating them, pandering to sensationalism, or using "bad" science, which can nurture conspiracy theories or incite public hysteria. In response, subsequent outreach efforts have offered accurate but simple and clear messages, relying on metaphors and analogies, and appealing to emotions, experiences, and normative beliefs.⁵⁴ Experiential, psychological, and sociocultural factors can shape public perceptions of risk and the ways in which people respond.⁵⁵

Framing messages about future, slow-onset climate risks in ways that connect with people's personal experiences and emotions can be complicated.⁵⁶

Political leaders may lack the kind of in-depth knowledge, incentives, or support they need to understand and prioritize climate change. It may be hard to juggle today's problems and pressures while giving due attention to what a changing climate will mean for the future.⁵⁷ For cities, climate change is one of many looming development issues and may not be the most visibly pressing.⁵⁸ Urban residents in the global South have unmet needs, for example clean water, decent shelter, accessible transportation, safe neighborhoods, and viable livelihoods. Even though climate change will exacerbate these problems directly and indirectly, this danger is more abstract than what is happening now and may not be politicians' most immediate concern.

In Boston, a state agency is responsible for the public transportation system, while different municipal and state agencies are responsible for the road network that traverses over 100 adjacent municipalities across the region. The historical role of metropolitan or regional planning agencies and the influence of funds from the federal government complicate the picture even further.⁶⁸ Numerous agencies and authorities with distinct yet highly interconnected roles and responsibilities have the challenging task of managing infrastructure that spans municipalities. To design adaptation programs that are “at scale,” public sector authorities like those in Boston must share communication arenas with equally powerful and informed local and regional actors, ranging from private entrepreneurs and neighboring governments to transnational networks.⁶⁹ Within these competing interests, cities must also find ways to appropriately balance the scope—in terms of both spatial and scalar reach—of any adaptation action.

Poor governance can hinder adaptation, particularly in the global South. A lack of transparency in decision-making, opportunity for public discourse, or means of seeking redress can allow elite interests to elbow aside those who are less politically and economically well-connected. Corrupt or inequitable systems, structures, and processes of governance heighten a city’s vulnerability to disasters and the impacts of climate change. Poor governance can especially jeopardize groups already marginalized and disadvantaged; and inequality, poverty, and displacement compound the ability to cope and adapt. Informal settlements pose a particular challenge. These have expanded in recent years, as record numbers of people have been uprooted by poverty, persecution, and violence. In 2016, 60 percent of refugees were living in urban areas rather than in camps.⁵⁹ Most informal settlements lie

outside the ambit of formal governance mechanisms, and planners often lack information about their vulnerabilities and developmental needs. This inhibits their ability to produce more inclusive adaptation plans.⁶⁰

Cities may lack the authority or autonomy they need to manage the risks they face. Spatially, cities have unique ecologies—including their ecosystems, built environments, and human communities—that are not clearly bounded.⁶¹ Decisions that need to be taken to protect humans and ecosystems in cities may require action at regional, national, and international levels, and this divided authority creates scale issues (see Box 2).⁶² Coordinating climate actions across diverse landscapes and populations is challenging. Those most susceptible to harm may hold the least influence over policy, and those asked to make sacrifices may not see what is in it for them. Differences between jurisdictions—social, cultural, political, legal, and ecological—can complicate matters as well.⁶³ Transboundary risks—such as sea level rise and storm surges—that span ecosystems and infrastructure networks make coordination across political jurisdictions vital.⁶⁴

Finally, planning and implementing adaptation and resilience strategies require investment, and cities typically lack the necessary financing. Even if they can secure it, they may not have the organizational capacity needed to spend the money effectively.⁶⁵ The scale of resources available for urban adaptation remains woefully small. Between 2010 and 2015, only 5 percent of the US\$1.83 billion dedicated to fund climate projects went toward strengthening urban climate resilience.⁶⁶ Only five such projects were approved. In addition, cities frequently do not have the agency or authority to access climate funds directly. Instead they must rely on allocations transferred from central, state, or provincial budgets. Funding from international finance institutions and multilateral and bilateral agencies typically requires political and economic negotiations between the donor and the country’s Ministry of Finance. This dynamic, and fierce competition for scant resources between and within countries, means cities that cannot directly access or manage loans, grants, or investment get pushed to the back of the queue. There are other hurdles for cities, including the need to analyze the additionality of investments—that is, whether they are actually contributing something new to adaptation. While important in principle, this is difficult in practice.⁶⁷

1.5. Structure of Paper

The structure of the paper maps onto the key knowledge gaps illustrated in Section 1.3 and ties directly to the key messages and high-priority action areas in Sections 5.1 and 5.2, respectively. In terms of methodology, the survey of literature for this paper draws on a web-based keyword search of academic articles, policy reports, and working papers from nongovernmental and multilateral sources. Notable examples, which are used to highlight particular innovative experiences, are drawn from assessing recent literature, from consultations with experts and practitioners, and from the authors' own professional experiences. To gather feedback on emerging findings and key messages, the authors conducted a web-based consultation with issue experts in March 2019, and an in-person consultation workshop in New Delhi, India, in April 2019. Attention was given to synthesizing key lessons (as illustrated by the various summary tables), as well as contributing to recommendations for potential solutions (Sections 5.1 and 5.2).

Section 2 assesses recent science on climate risks and impacts in cities, including a synthesis of the major trends in sea level rise, precipitation change, urban heat, changing disease vectors, and increasingly uncertain extreme events across the global North and South. Section 3 highlights exemplars of adaptation and resilience building around the world, focusing on experiences from particular plans, projects, and programs designed to increase adaptive capacity and resilience and urban equity and inclusion. We organize the discussion around the three priority action areas, which include spatial/infrastructure planning, people-centric or inclusive approaches, and nature-based solutions. Section 4 then offers a reflective assessment of key political, economic, and social enablers of climate adaptation in cities. To inform future action in cities, this section offers insights into how climate adaptation priorities can be applied in conjunction with climate mitigation, ecosystem protection, human security, and sustainable development objectives at the local level.

The concluding Section 5 draws out key lessons and strategies for scaling up urban actions (see Sections 5.1 and 5.2), and remaining key questions that researchers and policymakers will need to address. This focuses on urban adaptation actions that are either in planning phases or

are already being implemented. It considers whom climate adaptation interventions may affect, and how they have different impacts on different groups. It shows how social equity, inclusion, and justice are important in framing the social implications of policy designs and interventions. Thus, this paper offers a unique urban perspective, building upon existing and concurrent global assessments such as the IPCC's Special Report on Extreme Events (2012), the IPCC's Fifth Assessment Report (2014), the Sendai Framework on Disaster Risk Reduction (2015), the New Urban Agenda (UN-Habitat III), the IPCC's Special Report on 1.5°C Climate Change (2018), and WRI's World Resources Report series, *Towards a More Equal City* (2016–2020).⁷⁰

2. CLIMATE RISKS, VULNERABILITIES, AND THE COSTS AND BENEFITS OF URBAN ADAPTATION

The growth of urban centers across the globe has concentrated people, assets, and infrastructure, and fueled socioeconomic stratification.⁷¹ Cities are exposed to climatic hazards like the urban heat island effect, urban floods, and human-induced water scarcity.⁷² This section offers an integrated analysis of urban climate risks, vulnerabilities, and impacts. It does this by assessing recent research outlining the major trends in sea level rise, precipitation change, urban heat, shifting disease vectors, and increasing disaster impacts across the global North and South. It shows that pre-existing socioeconomic vulnerabilities, together with unequal exposure to environmental impacts lead to particular patterns of infrastructural, human, and environmental risks in cities. This section also provides broad quantitative and qualitative assessments of adaptation costs and projected benefits from the literature. It explains the economic, social, and political valuation, potential cobenefits, and "dividends" that make adaptation imperative.

2.1. Key Climate Impacts and Risks for Cities

Rapid growth of the urban population over the last two decades has multiplied both the number of people at risk and the threats to urban systems. The IPCC defines risk



Photo Credit: Flickr/Huitzil.

as the potential for uncertain outcomes where something of value for urban populations and decision-makers is at stake.⁷³ Risk results from exposure, hazards, and vulnerability. Recent assessments have identified key types of cities most exposed to extreme climate change impacts. Table 2 below offers a high-level synthesis of critical climate risks affecting cities. It is important to note that these risks will vary over time and place, and there is uncertainty in how they will manifest in specific cities. This is why localized data and projections of climate risks are essential.

Based on the risks outlined in Table 2, coastal cities—which host large populations, economic centers, and environmental hotspots—are especially threatened by climate change. Many of the world’s urban areas are situated in low-elevation coastal zones, regions susceptible to rising sea levels, and more frequent and severe storm surges. Though they represent just 2 percent of the world’s land area, low-elevation coastal zones are home to 10 percent of the global population (see Figure 4 for examples on Cairo and Dhaka).⁷⁴ Nearly two out of three

coastal inhabitants worldwide live in cities or towns, where the potential for asset damage or loss is significant.⁷⁵ Furthermore, economic and industrial activities concentrated in urban areas strain natural systems. Where environmental regulations, social protections, and infrastructure are weak, intensive economic activity can have especially deleterious consequences. Intensive water use, high inputs of chemicals, large volumes of toxic waste, as well as losses of natural habitat and ecosystems often turn portions of urban zones into environmental hotspots.⁷⁶ These factors, along with the loss of permeable surfaces and the conversion of vegetated land to developed land, compound the risk and exposure in coastal areas.⁷⁷

Water scarcity is another hazard, especially for cities in desert or dry climates. Drylands are estimated to cover about 41 percent of the Earth’s land surface and house approximately 2 billion people.⁸⁰ Such areas are characterized by extremely low and erratic precipitation, which often falls in intensive bursts that cause extensive erosion.⁸¹ Climate change is projected to increase water stress, with a cascade of direct and indirect impacts. In addition to threatening supplies of clean, safe drinking water, more frequent droughts can stop hydropower plants from providing adequate electricity to cities and towns. Water shortages will also affect food security (including its production and distribution) and human health. As glaciers melt, the flow of water to rivers like the Ganges and Brahmaputra and those in the Andes will slow, and the flow of some rivers that have supported human settlement for centuries could eventually become seasonal.⁸²

Beyond global trends and threats to ecosystems, it is important to note that impacts and needed adaptations to climate change are also highly localized. The composition of soils, vegetation, and shape and slope of topography affect drainage patterns, as do urban development patterns.⁸³ Impermeable surfaces, roads, and other barriers can channel water flows to specific geographies in a city. These features can interfere with natural hydrology and cause extreme flooding during regular seasonal rains.⁸⁴ Measures taken to decrease risk for one population sometimes shift risk elsewhere.⁸⁵ In this way, climate adaptation measures applied in one context may not always be appropriate or relevant when introduced in a different setting. Adaptation in one location may also lead to cascading impacts or even maladaptation in another.

TABLE 2

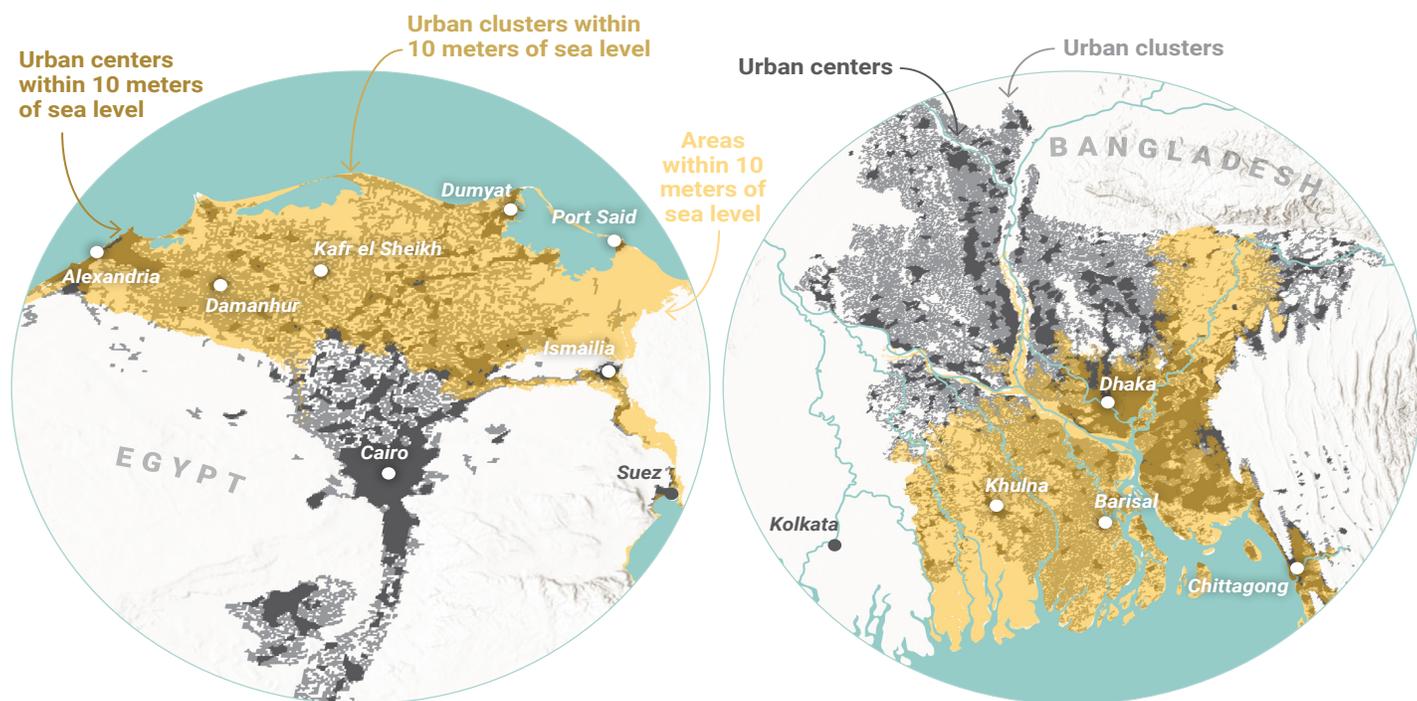
A Selection of Key Climate Impacts and Potential Risks for Cities

IMPACT	DESCRIPTION OF IMPACT	POTENTIAL URBAN RISKS
Temperature change	Temperatures are rising in cities around the world. Mean annual temperatures in cities around the world are projected to increase by 0.7 to 1.5°C by the 2020s, 1.3 to 3.0°C by the 2050s, and 1.7 to 4.9°C by the 2080s.	<p>In the short term, above-normal temperatures lead to heat waves (which exacerbate urban heat island effects) and below-normal temperatures lead to cold waves in cities. Poorly constructed shelters are at risk from heat stress, which can be compounded by indoor air pollution, scarcity of drinking water, increased prevalence of diseases, etc.</p> <p>In the long term, the combination of rapid urbanization, climate change, and population growth will increase stress on energy systems. Warming will intensify demand for cooling, which will pose threats to urban energy supply.</p>
Precipitation change	Mean annual precipitation in cities around the world is projected to change by -7% to +10% by the 2020s, -9% to +15% by the 2050s, and -11% to +21% by the 2080s.	Increasing potential for urban flooding and inundation, particularly for coastal and low-lying cities. Some cities will also experience more severe droughts.
Sea level rise	Climate change and sea level rise will exacerbate hazards such as storm surges, erosion, and saltwater intrusion. Sea level in coastal cities is projected to rise 4 to 19 cm by the 2020s, 15 to 60 cm by the 2050s, and 22 to 124 cm by the 2080s.	In the long term, coastal cities, urban aquifers, the built environment, transportation, and marine ecosystems will be severely affected.
Flooding and inundation	Flooding and inundation will exert additional pressure on existing urban water systems due to competition and demand for limited water resources. This will lead to negative impacts in health, economy, and environment.	Varies by location, depending on water stress. Large volumes of storm water runoff, rising sea level, changes in surface water and groundwater. For example, farmers in the urban periphery, housing in low-lying areas, and populations with little or no access to piped water will suffer most. Urban dwellers without tenure security, migrants, informal dwellers in risk-prone areas will also be affected.
Ecosystem change	Climate change and urbanization are likely to increase the vulnerability of biodiversity hotspots, urban species, and critical ecosystem services.	Ecosystem degradation can lead to the loss of biodiversity, open space, or green infrastructure that may serve as barriers to extreme climate risks. Clean air and water are also necessary for healthy cities. Nature-based solutions can present opportunities for green economies, social equity, and better health and quality of life.
Disasters and extreme risk events	<p>Climate change will increase the risks of morbidity, mortality, and mental illness in urban areas due to greater frequency of weather extremes.</p> <p>Climate-related disasters will disrupt movement of people and goods and have economy-wide impacts. Extreme impacts will also destroy existing physical infrastructure, such as melting asphalt and buckling railway tracks.</p>	<p>Extreme events will pose both short- and long-term risks to children, the elderly, the sick, and the poor disproportionately. Some chronic disabilities and health conditions (e.g. respiratory and heat-related illnesses) will be exacerbated by climate change. The experience of extreme impacts also induces mental stress and trauma.</p> <p>Interdependencies between transportation and other economic, social, and environmental sectors can lead to citywide impacts.</p>

Source: Based on Rosenzweig et al. 2018, modified by the authors.⁷⁸

FIGURE 4

Large Portions of Major Urban Areas Are in Low-Elevation Coastal Zones



Source: CUNY Institute for Demographic Research, Institute for Development Studies and the Center for International Earth Science Information Network (CIESIN) at Columbia University, 2019.⁷⁹

2.2. Key Vulnerabilities

Climate change threatens urban communities, assets, and infrastructure. For example, informal settlements in the global South are especially vulnerable to the impacts of climate change. It can be difficult to differentiate climate-specific impacts from those that stem from uneven development and informality.⁸⁶ However factors such as the poor quality or fragility of housing and work environments in these settlements, the precariousness of livelihoods, and residents' limited capacity to adapt⁸⁷ expose them to disproportionate risk. Disasters that disrupt transport, health care, public services, and labor markets can leave informal workers and settlement dwellers destitute and unable to cope. Despite the prevalence of autonomous coping strategies, such as various forms of community-based response mechanisms, systematic neglect by urban authorities makes it difficult to manage climate risks confronting this vulnerable population. Poor ventilation and sanitation; uninsulated, corrugated iron

roofs; and other hazards in informal settlements can magnify the effects of soaring temperatures, humidity, and heat waves, which can sicken and kill.⁸⁸ In many cases, local governments are favoring the urban political economic elite in decision-making at the expense of the urban poor.⁸⁹ Figure 5 summarizes key dimensions of urban vulnerability.

While the key sources of climate risks (see Table 2) and vulnerabilities (see Figure 5) are now known, and the urgency is clear, policymakers and citizens lack either the will or the means to respond. Often, decision-makers must seek economic justifications for specific investments. Financiers—including private investors, insurance firms, and donors—may demand this type of cost/benefit analysis. However, this information has been difficult to gather and measure due to a lack of data on “successful” adaptation actions, robust metrics on how to quantify adaptation losses and benefits, as well as uncertainties around the capacities and resources required



Source: Authors' synthesis.



Photo Credit: United Nations.

to adequately monitor complex, cross-sectoral adaptation actions. The section below attempts to synthesize existing information on adaptation costs and benefits from recent assessments.

2.3. Quantifying Adaptation Costs and Benefits

The costs of climate change will be high and will affect national economies. Average global economic losses could reach between 1 and 5 percent of GDP by 2100 under a 4°C increased mean temperature scenario, but regional losses could be substantially higher.⁹⁰ For example, by 2100, potential annual GDP losses for Indonesia, the Philippines, Thailand, and Vietnam could amount to 5.7 percent of GDP. This projected loss climbs to 6.7 percent if catastrophic risks are taken into consideration.⁹¹ Cities are often economically central to nations; therefore, risks to the economic functioning of urban areas will lead to significant impacts for national and global economic security.

Protecting the people, assets, and critical infrastructure crowded into urban areas will be expensive. However, less than 5 percent of global climate adaptation finance

between 2010 and 2014 was spent on cities.⁹² Coastal cities, in particular, confront the high cost of preparing for storms and floods. Sea level rise could reach 0.5 meters by 2050 and more than one meter by the end of the century. Recent studies put 800 million people in 570 cities at risk from rising seas and storm surges by 2050.⁹³ Another analysis finds that the value of assets in port cities exceeds US\$3 trillion (5 percent of gross world product in 2050).⁹⁴ It is unclear who will bear these costs.⁹⁵ Estimates of the annual cost of climate change adaptation range from US\$80 to US\$100 billion, and 80 percent of this is expected to be for urban areas.⁹⁶ The annual costs of coastal protection could reach US\$12 to US\$71 billion by 2100.

However, it is important to note that these expenses would be dwarfed by the cost of failing to prepare.⁹⁷ Global estimates predict that damage from sea level rise, storm surges, and flooding linked to climate change could cost cities US\$1 trillion each year by mid-century, meaning that financing global adaptation would be one-tenth as expensive as taking no action and dealing with the consequences.⁹⁸ Considering potential losses and other consequences of climate change, investing in proactive

climate resilience and adaptation today is highly cost-effective. Conservative estimates indicate that US\$1 invested today in disaster preparedness can avoid US\$4 in postdisaster reconstruction.⁹⁹ Where climate insurance is feasible, the estimate on returns is US\$7 per dollar paid.¹⁰⁰ The need for such investments can be particularly acute in places hit by repeated shocks and stresses. Leaving these places exposed can trigger a downward spiral, especially for poor populations, that can be hard, if not impossible, to break. Investments to strengthen resilience in advance of these disruptions can both limit losses and hasten recovery, giving rise to a “resilience dividend”.¹⁰¹

Cities can save money by making climate resilience an integral part of their planning. Implementing adaptation plans in cities can also help respond to other challenges, especially if cities are building adaptation into investments they need to make anyway. Studies show that to meet the growing demand for physical infrastructure and to address infrastructure deficits, cities will need to double annual capital investments to more than US\$20 trillion by 2025.¹⁰² One study calculates that US\$5 to US\$6 trillion will be required each year and that the annual deficit in infrastructure investment will be US\$1 trillion a year.¹⁰³ Seventy percent of these projected investment needs will be in emerging and developing countries.¹⁰⁴ By 2050, the World Bank estimates that US\$11 to US\$20 billion will be needed annually to safeguard urban infrastructure against climate risk. The United Nations Environment Programme’s (UNEP’s) report includes more types of infrastructure and predicts that protecting them will cost them close to US\$120 billion by 2030.¹⁰⁵ Building basic infrastructure for urban resilience, such as piped water supplies, sewers, storm water drainage, and electricity that many cities in the global South lack, would likely cost still more. However, it is important to note that weak infrastructure systems come at a price. For example, the World Health Organization (WHO) reports that providing clean drinking water to all city dwellers would cost US\$141 billion over five years, but total global economic losses from unsafe water and sanitation systems are 10 times that high.¹⁰⁶

The economics of adaptation are not always straightforward or equitable, so attempts to quantify costs and benefits can be misleading. Measures to increase adaptive capacity can result from effective planning and restructuring of service delivery. Rather than added costs, these may require shifts in governance, operations, and

budgeting processes. Some benefits, such as preventing death or promoting social welfare, can be harder to measure, but are nonetheless critically important. Judgments about what to protect are not straightforward. A city may determine that a high-cost infrastructure project, such as a sea wall, makes financial sense to protect an economically valuable property. The calculus would look different if the area at risk were a fishing community or informal settlement where financial assets and economic output were low or unmeasured. Decisions about what actions to take are therefore built upon an implicit and explicit calculus of what (and who) is valued and how.¹⁰⁷ There is also great uncertainty on the long-term economic returns of adaptation and development investments, which are often difficult to monetize.¹⁰⁸ This is problematic from an equity perspective. Traditional methods of evaluating the benefits and costs of actions therefore must be modified to better account for uncertainty and foster greater equity.

3. DEVELOPMENT DIVIDENDS FROM INTEGRATED ADAPTATION ACTION—CITIES MAKING STRIDES

Having discussed key climate impacts, their risks for cities, and the economics of adaptation actions, we now move to assessing emblematic climate adaptation and resilience-building efforts in cities across the global North and South. We highlight the need to take an integrated approach to adaptation in urban areas to avoid conflicts with other priorities such as housing, transport, recreation, and industry. In view of the potential development dividends associated with urban adaptation, we illustrate three broad priority areas: spatial and infrastructure planning, people-centric and inclusive approaches, and ecosystem-/nature-based solutions. These priority areas are described in Sections 3.1, 3.2, and 3.3, respectively, and are reinforced through Figure 3.

Section 3.1 explores what cities are already doing from a spatial planning perspective. This includes investing in sustainable infrastructure (see Section 3.1.1), incorporating adaptation into land use planning, and factoring climate risk into other municipal policies and regulations (see Section 3.1.2). Section 3.2 documents emerging people-centric or inclusive approaches to adaptation in cities.

Examples include building social resilience and reducing poverty (see Section 3.2.1), and improving health, security, and well-being (see Section 3.2.2) in underserved and at-risk communities. Section 3.3 illustrates notable nature-based solutions, focusing on potential dividends between adaptation and climate mitigation and pollution control (see Section 3.3.1), and ecosystem protection (see Section 3.3.2). In this section, we pay special attention to tier two and three cities in the global South, where urbanization is taking place the fastest, municipal budgets are modest, local technical capacity is often low, and vulnerability to climate impacts is high. Although we note that many cities are already centers of adaptation action, these efforts need to be supported, scaled, and contextualized across more cities.

3.1. Spatial Planning and Infrastructure Delivery

3.1.1. MAINSTREAMING CLIMATE ADAPTATION INTO DEVELOPMENT AND INFRASTRUCTURE DELIVERY

Climate change and development are closely related through three conceptual links. First, climate change is the direct result of unsustainable development. Second, sustainable development can reduce vulnerability to anticipated impacts and mitigate future emissions through improved resource and institutional management.¹⁰⁹ Lastly, climate impacts threaten to erode past gains in reducing poverty as well as society's capacity to effectively adapt.¹¹⁰ The literature on climate justice notes that modifications to the atmosphere that threaten future persons are, therefore, unjust.¹¹¹ Similarly, on the development side, theories on more inclusive and "alternative" development stress the role of the rights of the marginalized and disempowered, local knowledge, and popular grassroots movements.¹¹² Most of these relationships illustrate that climate change, and especially the issue of adaptation, involve trade-offs and, sometimes, uncomfortable choices between industrial development, environmental sustainability, and risk and vulnerability reduction.¹¹³

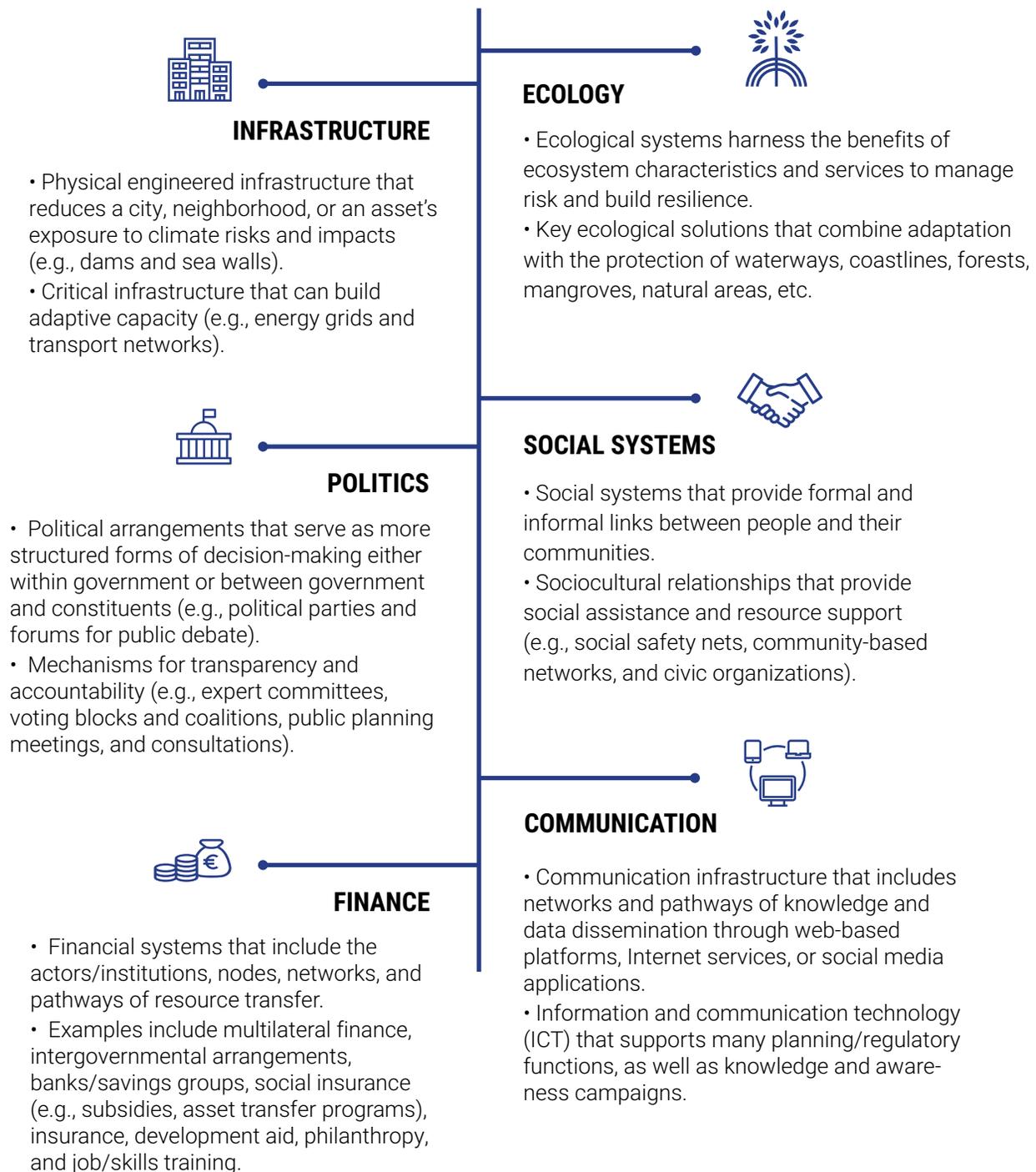
Rather than seeing climate and development as antithetical, many scholars have introduced the idea of "mainstreaming" adaptation into development planning and

implementation. The rationale here is that adaptation can both build people's capacity to cope with climate change and contribute to their livelihoods.¹¹⁴ This integration takes place at a range of governance levels—local, national, and global.¹¹⁵ For example, cities can embed climate change adaptation into different urban development paradigms. Framing climate change as a development priority—to spur both economic growth and scientific innovation—can attract investment and galvanize action.¹¹⁶ Others frame climate change in terms of public health, national security, mobility, and infrastructure development or disaster risk management.¹¹⁷ Natural disasters often trigger greater public awareness and political impetus for urban climate adaptation planning.¹¹⁸ For example, Hurricane Sandy in 2012 prompted New York City to retrofit and construct new infrastructure to prepare for future risks.¹¹⁹ Communicating adaptation cobenefits can help to connect mitigation, adaptation, and risk management priorities to other social, economic, and political objectives that are at the forefront of people's minds.¹²⁰ For cities in the global South, a connection between climate change and development may yield further buy-in from politicians.¹²¹

Given the close relationship between adaptation and development, many cities have articulated adaptation needs within existing and forthcoming strategies for improving infrastructure and public services. Infrastructure—including roads, railways, ports, and telecommunication networks—is critical to the functioning of urban systems; the flows of goods, resources, information, power, and people through them;¹²² and their resilience in the face of climate change risks.¹²³ More climate-informed infrastructure planning and capital investments can lead to more innovative thinking around what can be done differently in the infrastructure cycle. For example, infrastructure can be sited in less hazard-prone areas or regulated more stringently. Existing buildings and infrastructure can be retrofitted, with considerations of lifecycle costs and more flexible design standards embedded within more effective disaster preparedness and response mechanisms. These approaches can reduce maintenance costs and increase building and infrastructure lifetimes. Figure 6 illustrates key urban infrastructure and development domains that are relevant to adaptation action.

FIGURE 6

Key Urban Infrastructure and Development Domains Relevant for Climate Adaptation



Source: Authors' synthesis.

3.1.2. SPATIAL PLANNING, POLICIES, AND REGULATIONS INFORMED BY CLIMATE RISKS

Local governments that have begun adaptation planning tend to formalize this process within their jurisdiction, which helps to legitimize, facilitate, and coordinate projects across sectors and departments.¹²⁴ Integrating adaptation priorities into municipal laws, rules, and regulations can be key to ensuring that they are recognized and implemented in practice. Spatial planning informed by climate risks can ensure that settlements, assets, infrastructure, and services are located away from potential hazards, while fostering equitable access to services and the opportunities of the city (see examples of Rotterdam in Box 3 and Semarang in Box 4). Larger primary cities often enjoy some level of regulatory autonomy, meaning that they are able to devise, evaluate, and apply regulations. They tend to have authority over taxation, land management, and zoning regulations. In other cases, national governments and the private sector may work with cities to incentivize adaptation, or create, explain, and implement new rules. For example, in 2012, the government of Australia

produced a regulation on climate adaptation calling for stricter performance-based building standards, national incentives to encourage adaptation in cities, and regulatory approaches that respond to evolving needs and avoid using the past to predict the future.

Air quality, stormwater discharge, coastal flood protection, ecosystem protection, freshwater management, and public health/sanitation are all vulnerable to the impacts of climate change. So the regulations that cover them need to be included in adaptation plans. This would help to synchronize expertise and financial resources to meet interconnected environmental challenges. But integrating adaptation requirements at the local level is made harder by current regulatory and legal arrangements. Often these are too rigid and static to meet the needs of rapidly growing cities facing the repercussions of a changing climate.¹²⁸ As Birkmann et al.¹²⁹ note, even though various urban planning tools, such as land use plans and zoning regulations, do consider climate change and natural hazards, they often operate within the assumption that what has happened in the past will continue to happen in

BOX 3

CASE: A Comprehensive Adaptation Strategy in Rotterdam, the Netherlands

As a low-elevation harbor city, Rotterdam faces sea level rise, saltwater intrusion, and storm surges. To respond to extreme flooding and water-related risks, Rotterdam has transitioned from viewing water as an isolated policy arena to a holistic, multisectoral policy sphere.¹²⁵ In 2009, the city of Rotterdam designed Rotterdam Climate Proof (RCP) to build upon the Rotterdam Climate Initiative (RCI), which was Rotterdam's signature mitigation policy. The goal of the RCP was to envision a "climate-proof" city by 2025, increasing the city's engagement with climate change across all policy domains, and to develop an institutionalized climate governance structure between the city government and local stakeholders. The RCP also had three ancillary action goals, which were meant to enable knowledge and innovation on water and spatial development, implement green infrastructure projects, and market RCP's work to other cities. During this period, Rotterdam developed a reputation as an innovative city and assumed the role of a knowledge distributor in C40 Cities Climate Leadership Group and other networks, particularly in the area of adaptive water management.

In 2013, Rotterdam published its Adaptation Strategy, which aimed to increase capacity and centralize decision-making authority to address Rotterdam's increasing vulnerabilities. Rotterdam's Adaptation Strategy sought to blend sectoral policy arenas, integrate planning domains, and mix local government actors with stakeholders in a new fashion.¹²⁶ Because the RCP managed the scoping of the Adaptation Strategy, the city government paid attention to building coalitions with the Port of Rotterdam Authority as well as the private sector to facilitate greater learning and cooperation throughout the policy process.¹²⁷ When Rotterdam became a member of the 100 Resilient Cities network, many of these lessons were shared with other cities through the "Platform Partners" service.

As a low-lying coastal city, Semarang is susceptible to both sea level rise and river inundation. Semarang's vulnerability assessment showed its vulnerability to flooding, and its recent Resilience Strategy (2016) noted the importance of strengthening riverbanks, fortifying coastlines, and implementing early warning systems.¹³⁴ The city government implemented a Flood Early Warning System (FEWS) project. The project was conducted between 2012 and 2014 and was located in the Beringin watershed. It created an early warning system and evacuation strategies to alert and protect vulnerable communities. Semarang subsequently joined 100 Resilient Cities and has also experimented with early forms of crowdsourcing technology. Different digital portals now collect social media information for emergency response purposes. This technology now supports different response efforts by community and volunteer groups during disaster events.

the future. Thresholds for restrictions of future settlement and development are most often based on observations of the past (such as past flooding or coastal inundation events) and are fixed to one hazard scenario and single development strategy. This is problematic since flood patterns observed in the past are changing due to climatic and land use changes.¹³⁰ The city of Houston experienced three so-called 500 year floods in the space of just three years.¹³¹ Conversely, tightening regulations may yield unintended negative consequences, such as displacing people from their homes. So local governments must focus on making adaption action palatable and fair in dynamic urban environments.

Physical planning and design for adaptation typically involves conventional zoning and building regulations, land use planning, and urban design. Local and regional zoning and land use regulations aim to eliminate or minimize slow and/or rapid onset risks. They enlist measures such as controlled retreat (relocating residents, businesses, and infrastructure from high-risk areas); avoidance (restricting, preventing, or containing growth and development); or accommodation (modifying or converting land use).¹³² Moving people away from risk-prone informal settlements can reduce longer-term risks while significantly improving living conditions. For example, with community input and participation, the city of Rosario, Argentina, resettled people from informal settlements to new locations with better services and infrastructure, improving their livelihoods, health, and quality of life.¹³³ However, such measures sometimes entail higher economic and social

costs, breaking social networks and reducing access to employment. Building codes and architectural guidelines can promote climate-responsive buildings that adapt to changing environmental conditions. Planning and zoning regulations can also expand soft land cover and green infrastructure, contributing to mitigation by enhancing air quality, conserving energy, and sequestering carbon, while also preserving and expanding habitats. For example, New York City's recent Waterfront Revitalization Program (2018) promotes building setbacks, permeable surfaces, and planting trees along the waterfront. Ecological infrastructure and ecosystem-based adaptation are explored in Section 3.3.

New information and communication technologies (ICT), data, and modeling can inform spatial and infrastructure plans. Technology now exists that enables us to see changes in the built and natural environments using high-resolution satellite data. Such data can include topographic and elevation maps, relevant weather and climate information, remote sensing data, localized climate risk models, and vulnerability assessments. These geospatial data can be coupled with disaggregated socioeconomic data and decision-support tools for governments and residents. A data-driven approach to adaptation can make it possible to visualize potential climate impacts and risks to specific assets and neighborhoods (see examples in Box 5). Collaboration between local research institutions, civil society, community groups, the private sector, and city governments can address gaps in information and capacity and can provide a huge return on investment.

3.2. People-Centric and Inclusive Adaptation Approaches

3.2.1. SOCIAL RESILIENCE AND POVERTY REDUCTION

The growing scholarship on social resilience and community-based adaptation reveals that improvements in local adaptive capacity can be tied to efforts to redress development inequalities.¹³⁷ Examples of community-based adaptation include the formation of community water collectives, microcredit groups, and stronger social safety nets through increased social interaction, problem-solving, learning, and mutual support.¹³⁸ These strategies offer different opportunities to address lagging structural and institutional capacity to adapt to climate impacts.¹³⁹

Inclusive approaches to climate change policymaking in cities emphasize the representation of divergent voices and interests. Procedural inclusiveness entails bringing communities into the policymaking process that have traditionally been marginalized due to class, ethnicity, age, gender, or other socioeconomic categories.¹⁴⁰ For example, in the late 2000s, a citizen's climate change panel was established in Quito, Ecuador, with representation from youth groups, indigenous communities, and local

women's associations. This panel advocated for a set of guiding principles to prioritize actions that balanced mitigation, adaptation, and sustainable development needs.¹⁴¹ Similarly, cities in South and Southeast Asia that participated in the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN) facilitated a series of "shared learning dialogue" workshops that brought diverse stakeholders together to envision appropriate actions to improve urban climate resilience.¹⁴² The case study of Gorakhpur, India, in Box 6, provides a good example of how this works. Such inclusive programs have been prevalent in the United States as well. Climate change plans in New York City, Chicago, and San Francisco all advocated for broadly representative risk and vulnerability assessment approaches.¹⁴³ The objectives of these programs were to improve citizen awareness of and action on issues—that is, to develop civic capacity and knowledge to deal with uncertainty—while also legitimizing eventual climate change policy, planning decisions, and their outcomes.

Community-based adaptations are an important, direct way to target populations that may bear disproportionate risks. Table 3 highlights examples of community-based adaptation plans around the world. In spite of policy

BOX 5

CASE: Role of Information and Communication Technologies

Cities are information and technology powerhouses, spreading information that has nurtured innovation, social advancement, and economic growth. New information and communication technologies (ICTs) have been deployed to create early warning systems, monitor air quality, energy use, emissions, and hydrological processes. But they have rarely been used to support long-term adaptation or share learning from successful experiences. One critique is that ICT-based solutions can entail high initial costs associated with siting new infrastructure, so cheaper alternative solutions may provide better, more immediate adaptation benefits.

In Ghana, the University of Legon and collaborators have installed real-time water-level sensors for weather and hydrologic monitoring of the River Odo, which runs from the highland areas outside Accra and eventually to the outfall in the Atlantic Ocean.¹³⁵ Such sensors provide a critical early warning system for communities living on the river. In Chengdu, China, monitoring sensors have been deployed to provide real-time data on hydro-logic changes to help protect multiple cities in the lower valleys of the subcatchment areas.¹³⁶ While data and information can provide a valuable input for transformative adaptation, more experimentation and practice is needed in this space.

Beginning in 2009, the city of Gorakhpur, India, became actively involved in urban climate resilience building, developing a climate resilience strategy and implementing several resilience building interventions. Gorakhpur is one of the fastest-growing cities in the Indo-Gangetic plains, though the urban systems have not kept pace with this rate of growth.¹⁴⁴ The city regularly experiences flooding and waterlogging. Although the mayor and other city leaders supported the climate resilience agenda, their ability to meaningfully promote citywide change was constrained by larger governance problems. India's 74th Constitutional Amendment Act is supposed to decentralize power and delegate basic service provision to urban local bodies; however, this has been unevenly enacted. The state of Uttar Pradesh, where Gorakhpur is located, has not fully implemented this decentralization, which has meant that local authorities lack the agency and financial means to make decisions over the functions and services in their jurisdiction.

To overcome this hurdle, Gorakhpur pursued ecosystem-based adaptation actions that could yield multiple benefits through grassroots-led efforts. A civil society organization, the Gorakhpur Environmental Action Group (GEAG), led much of this effort and helped stakeholders in the city identify an opportunity to strengthen resilience. They did this by launching a project in the peri-urban zone of the city with four interlinked goals. These were to develop models of climate-resilient integrated agriculture; improve income and food security for poor and vulnerable populations; ensure the sustainability of peri-urban agricultural lands through different regulatory and incentive mechanisms; and improve the flood buffering capacity of the city through the sustainable management of agricultural ecosystems.¹⁴⁵

A formative evaluation found that farmers in Gorakhpur's peri-urban areas who participated in this project more than doubled their average agricultural income through lower input costs, crop diversification and intensification, expansion of the land under cultivation, and reduced crop losses from flooding and other natural hazards.¹⁴⁶ GEAG's efforts also strengthened market linkages and product pricing, which helped raise incomes and enhance food security.¹⁴⁷



Photo credit: Anna Brown

TABLE 3

Select Examples of Participatory and Community-based Adaptation Plans

LOCATION	DETAILS
Baltimore, MD, US	Baltimore's updated Sustainability Plan (2019) has a strong focus on equity. Its detailed explanation, outcomes, and indicators directly related to equity/inclusivity. The process was highly participatory, including a wide array of Baltimore residents.
Seattle, WA, US	Seattle's 2035 Comprehensive Plan (2005) has a strong focus on inclusivity throughout the process, policy, and impact. It set this priority by acknowledging historical discrimination, displacement, etc.—issues that citizens brought up at community meetings.
Durban, South Africa	Durban's Resilience Strategy (2017) notes that collaborating with informal settlement residents is one of the main objectives.
Dhaka, Bangladesh	ActionAid has been facilitating community-based adaptation by fostering community-awareness and empowerment programs for the last two decades.
Lami, Fiji	After Cyclone Winston in 2016, the Fijian government partnered with the civil society organization, People's Community Network, and began a project to map socioeconomic data, adaptation actions, and settlement analysis. This scenario study compared ecosystem- and engineering-based adaptation options. Estimated benefits ranged from F\$8–F\$20 for every F\$1 spent.
Greater Geraldton, Australia	The Batavia Regional Organisation of Council's Climate Change Adaptation Action Plan (2010) included a series of consultation events for local residents. Proposed adaptation actions were assessed according to "win-win," "no regrets," or "cost effectiveness" criteria. Members of the public also identified opportunities for cross-agency collaboration in the region.
Quito, Ecuador	In the late 2000s, Quito established a citizen's climate change panel with representation from youth groups, indigenous communities, and local women's associations. This panel advocated for a set of guiding principles to prioritize actions that balanced mitigation, adaptation, and sustainable development needs.
Dosquebrada, Colombia; Santa Ana, El Salvador; Santo Tomé, Argentina	Three cities hosted adaptation workshops to analyze problems and trade-offs and propose a portfolio of options. Community participants highlighted the need to establish a common vulnerability and risk baseline, develop comprehensive plans of land management, define green and gray infrastructure needs that reduce risks, and strengthen a communication strategy. This generated project proposals for city portfolios that included reforestation with native vegetation and recovery of creeks and streams within urban and peri-urban areas.
Maputo, Mozambique	Maputo established a participatory urban planning process for climate-compatible development, with a focus on underserved and informal settlements. The processes included community workshops, open meetings, and risk mapping, and demonstrated that the coproduction of knowledge contributed to a better understanding of structural inequalities in relation to climate change over three years in the early 2010s. However, challenges remain in understanding the relevance of climate information at the neighborhood level.
Surabaya, Indonesia	In the late 2000s, informal houses that encroached on rivers were voluntarily moved back by residents to make way for a riverside path to facilitate dredging of the river by the municipality. This project improved the local environment and reduced the risk of floods. In response to calls for their eviction, residents of informal settlements mobilized to show that they should be seen as the "guardians of the river" rather than for using the river as a solid waste dumpsite.

Source: City of Baltimore 2019; City of Seattle 2005; City of Durban 2017; Batavia Regional Organisation of Councils 2010; Carmin et al. 2012; Anguelovski et al. 2014; Hardoy et al. 2019; Broto et al. 2015; UN-Habitat 2018.¹⁴⁹

efforts to stitch together sets of adaptation measures that link citywide and community-based efforts, more significant strides are needed in this domain. It should be possible to integrate the knowledge, perspectives, and needs of different communities into more top-down and government-led resilience and adaptation-building efforts. However, it is hard to find examples of this being done in any meaningful way.¹⁴⁸ The notion of “participation” has in many ways been mainstreamed in development practice, but this principle is applied as merely a box that must be ticked. Additional progress is needed to flip the epistemological frame so that the experience and knowledge across marginalized and poor communities is valued and plays a foundational role in framing the problem, identifying solutions, and evaluating adaptation benefits.

3.2.2. URBAN HEALTH, SECURITY, AND WELL-BEING

The nexus between cities and health is a growing field of interest for analysis and policy intervention. Protecting city populations from infectious diseases and other health outbreaks with transboundary effects is a key concern for urban managers and nation states. A recent *Lancet* study showed how climate risks can lead to undernutrition and cardiovascular, respiratory, and water-borne and vector-borne diseases.¹⁵⁰ Climate stressors can also jeopardize mental health. A recent study from the United States documented this link, showing a 2 percent increase in the cases of mental illness diagnosis across the population associated with a 1°C rise of five-year warming.¹⁵¹ Climate change is also expected to increase the death rate from exposure to ozone, fine particles, and other airborne pollutants.¹⁵²

In addition to worsening air quality, climate change threatens human health by contributing to heat waves. Other dangers include new diseases, more noncommunicable diseases, and food shortages. Although data on the climate change burden of disease and injury are not refined enough for proper detection and attribution, evidence does suggest that climate-induced health risks can reinforce each other. The most documented and analyzed relationship between health and development is the loss of productive labor using the disability-adjusted life years (DALYs) methodology.¹⁵³ Thus, more transformative

adaptation strategies that combine preventive responses and integrate green (flora); blue (water); and cultural, economic, and gray (traditional-built) infrastructure in urban development has potential to protect human health while also supporting the urban economy.

Climate change can imperil security and political stability. As resources dwindle in fragile ecologies, competition and conflict over these resources can ignite. Climate change has uprooted people by worsening floods and droughts, destroying livelihoods, degrading landscapes, and jeopardizing food supplies. Many have flocked to cities. Studies show how unrest in cities often stems not from the quest for political change, but from competition for scarce resources and the inability to meet basic needs.¹⁵⁴ Transformative adaptation would therefore have to gauge and address the health, security, and development risks associated with climate change to address the potential for conflict. In this case, adaptation can help protect human security as well as health and development. The case study from Indore, India (see Box 7) illustrates some of these adaptation dividends.

3.3. Nature-based Solutions

3.3.1. CLIMATE MITIGATION AND POLLUTION CONTROL

Cities can mitigate climate change by shifting to renewable energy, transforming transportation systems, and helping improve energy efficiency in homes, factories, and other businesses. These measures can also generate adaptation cobenefits.¹⁶¹ Urban areas are investing in rapid bus transit and other mass transit systems and redesigning neighborhoods that are walkable. Cities are also spearheading the transition toward renewable energy. Reducing greenhouse gas emissions from cars and buildings generates the cobenefits of improved air quality, better health, and lower medical costs. Climate mitigation in cities can also spur cobenefits by creating green jobs, improving mobility, and strengthening inclusion. Energy sources that contribute to a circular economy include efficient use of biomass energy, recycling of organic waste to energy, tapping the methane from landfills, and decentralized nature-based treatment of sewerage plants (which directly reduces energy use and emissions).

Indore, a city in Madhya Pradesh, India, illustrates the many ways that restoring ecosystems and using natural infrastructure can promote health and well-being. Water is scarce in Indore, and climate change heightens water stress.¹⁵⁵ The city undertook an effort to restore its 26 urban lakes, many of which are located in the peri-urban zones, to serve as an emergency water supply.¹⁵⁶ Many of these water bodies had been filled in through a combination of eutrophication and waste. The process that led to this initiative and its implementation brought diverse communities together. It was facilitated by TARU Leading Edge with support from the Asian Cities Climate Change Resilience Network (ACCCRN), funded by the Rockefeller Foundation, and undertaken in conjunction with the municipal government and a range of civil society organizations. It included technical innovations in waste management. Artificial floating islands were introduced to help purify the water, serve as bird habitats, and improve the aesthetic quality of urban lakes.¹⁵⁷ Equally important was the establishment of local Water Conservation and Management Committees (WCMCs), which regularly monitor the lakes for improper waste disposal and for clean up. These efforts improved water quality so that it is now safe to use the lakes as an emergency water supply. This institutional dimension has been important not only for the longevity of the project, but also for galvanizing a new base of community champions promoting environmental protection.¹⁵⁸ It has also helped to build social capital among community members, an important aspect of community resilience.¹⁵⁹ The Indore case demonstrates how thoughtful approaches to building climate resilience can create an alternative to programming patterns that engage a narrow set of actors.¹⁶⁰

Alternative approaches to sewerage treatment can provide climate mitigation and adaptation benefits, while also generating economic and social advantages. Models that manage fecal sludge to produce energy briquettes, for example, can also spur medium-size businesses, supporting both job growth and sustainable energy sources for populations in more rural areas. Sludge and organic waste can also be used to grow food. The cobenefits of this transformative adaptation include providing better nutrition for urban dwellers; reducing pollution;¹⁶² supporting urban and peri-urban agriculture; expanding green infrastructure (e.g., green roofs), local markets, social (food) safety nets, and alternative food sources; and requiring people to drive fewer miles to supply and access food.¹⁶³

3.3.2. ECOSYSTEM PROTECTION

Historically, cities have undervalued and overrun their natural environmental assets, treating them as add-ons to the built environment. The results have been a continuous loss and fragmentation of ecosystems. The ecosystems in and around cities are now considered key places for

biodiversity protection. Protecting and restoring these ecosystems can also provide vital services to urban inhabitants, including access to water; flood control; tempering the urban heat island effect; acting as a buffer to waves and wind; and stabilizing coastlines, riparian zones, and hill slopes.¹⁶⁴

Nature-based or ecosystem-based adaptation uses natural ecosystems and capital to assist in adaptation, based on the principle that intact and healthy ecosystems are more resilient to climate stressors and provide more social benefits.¹⁶⁵ The International Union of Conservation of Nature (IUCN) describes nature-based solutions as an umbrella concept that includes approaches to ecosystem restoration, climate adaptation services, green infrastructure, integrated natural resources management, and area-based conservation.¹⁶⁶ Nature- or ecosystem-based adaptation is intended to strengthen resilience and simultaneously reduce poverty, reducing stressors on ecosystems to enhance ecosystem services. It can include targeted management, conservation, and restoration activities, such as protecting, expanding, or connecting



Photo Credit: Alex Punker.

ecosystems or restoring natural infrastructure like barrier islands or coral reefs to reduce the risk of disasters. It can also protect or restore biodiversity, support economic livelihoods, and remove atmospheric greenhouse gases. It is thus promoted as a win-win solution.¹⁶⁷ The benefits can be extensive. Water protection can fuel economic growth; mangrove protection creates buffers against storm surges; and protecting floodplains can recharge groundwater supplies. Many of these actions provide low-cost wastewater treatment, restoration of degraded ecosystems in cities for multiple uses, and protection of terrestrial ecosystems that preserve biodiversity and provide essential resources.

Natural systems can offer more cost-effective pathways to climate adaptation and strengthened resilience than traditional “gray” infrastructure (such as seawalls, dams, etc.), as the Quy Nhon example in Box 8 suggests. It is cheaper to protect watersheds by limiting development and the types of activities permitted in a water-source area than to install expensive downstream water treatment facilities to purify water from toxins and other

substances deleterious to human health.¹⁷³ Ecosystem-based prevention is both cheaper and more flexible than remediation. The uncertainty surrounding climate projections and local impacts places a premium on solutions that can accommodate a range of future economic, demographic, and environmental scenarios.¹⁷⁴

Ecosystems protection helps slow climate change, as well as insulate cities from its effects, because restoring natural ecosystems can sequester carbon. Twin benefits—adaptation and mitigation—flow from planting trees, promoting sustainable agriculture, and preserving coastal wetlands and peatlands.¹⁷⁵ Ecosystem-based adaptation can also enhance agricultural productivity, food supplies, and nutrition by fighting erosion and improving the soil.¹⁷⁶ One notable initiative is the “Sponge Cities” program in China, where the Ministry of Housing and Rural-Urban Development, the Ministry of Finance, and the Ministry of Water Resources have, since 2014, implemented water management plans that treat the city like a “sponge,” absorbing, storing, infiltrating, and purifying rainwater and subsequently releasing it for reuse when needed.

In coastal cities, mangroves provide an important physical buffer to storms and waves while also offering opportunities to diversify livelihoods.¹⁶⁸ Mangroves across Vietnam had been degraded by urban development and aquaculture, making coastal cities more vulnerable to the effects of climate change.¹⁶⁹ Quy Nhon, in mid-coastal Vietnam, launched a 150-hectare mangrove restoration project in Thi Nai Lagoon (see Figure B1). The Thi Nai Lagoon abuts a part of the city located in a growth corridor, which also falls within a floodplain. Prior to the project, in 2009, Typhoon Mirinae struck Quy Nhon and resulted in the deaths of 122 people, widespread property destruction, and an estimated US\$22 million in damages, according to Quy Nhon City's Economic Development Department.¹⁷⁰ This event triggered a temporary pause on development in the floodplain. The mangrove restoration project in Thi Nai Lagoon is helping shield the area from rising sea levels and more intense and frequent storms. Behind the mangroves, farmers and others could return to work. A cost-benefit analysis estimated that local people will earn twice what they would have if they had sacrificed the mangroves and relied only on aquaculture for their livelihoods.¹⁷¹

FIGURE B1

Timeline of the Mangrove Restoration in Quy Nhon, Vietnam



Source: Roberts et al. 2012; Brown et al. 2012; DiGregorio 2015; Tuan and Tinh 2013.¹⁷²

FIGURE 7

Urban Planning with Nature-based Solutions for Climate Adaptation



Source: Anguelovski 2013; Frantzeskaki et al. 2017; C40 Cities 2019; Li et al. 2017, UN-Habitat 2018.¹⁷⁸

FIGURE 8

Ecosystem Functions within and beyond City Boundaries



Source: Adapted from WRI’s Cities4Forests.¹⁸²

Already applied in more than 30 cities across the country, the Sponge Cities initiative has further promoted flood control, water conservation, water quality improvement, and natural ecosystem protection.¹⁷⁷ Figure 7 illustrates additional notable examples of ecosystem-based adaptation in cities.

While natural infrastructure and thriving ecosystems play an essential role in climate adaptation, the benefits may not be distributed evenly. In cities with shortages of affordable housing, green infrastructure is ushering in “green gentrification.”¹⁷⁹ Soaring property values that force some populations out can exacerbate social and economic inequities and disrupt social and community ties. This can erode adaptive capacity and resilience, so caution is needed to anticipate a range of possible outcomes and ensure that greening efforts do not bring unintended consequences. Policies, subsidies, and social protections should be geared to avoid economic displacement.

An obstacle to enlisting ecosystems in climate adaptation is that the boundaries of ecosystems and cities often do not match one another. The administrative jurisdiction of a city does not correspond with the area needed to support the dense population of city dwellers. Vital resources and services, such as water and food, come from areas outside the urban core—in peri-urban zones as well as more distant ecosystems (see Figure 8).¹⁸⁰ Often, multiple agencies across different scales control the land and services—including ecosystem services—outside city limits, creating a challenge of governance.¹⁸¹ The example from Durban, South Africa, exemplifies how once a city created a partnership across municipal boundaries to implement nature-based solutions (see Box 9).

BOX 9

CASE: Ecosystem Protection and Management in Durban, South Africa

Durban is the largest city and port on the east coast of Africa and the third largest of South Africa’s metropolitan areas. Two-thirds of the municipality remain rural, but these areas are urbanizing rapidly. Among South Africa’s major cities, Durban has the highest percentage of people in poverty. Durban also has considerable backlogs in infrastructure and basic services. Climate projections suggest that the city can expect hotter temperatures and more variable rainfall, sea level rise, and compounding storm surge. This puts the city at risk from both sudden and slow-onset disasters, ranging from flash floods and droughts to coastal erosion and storm surges exacerbated by sea level rise, calculated to be 2.7 millimeters (mm) per annum.

The city set up a multistakeholder, transmunicipal partnership to examine how ecological infrastructure could safeguard water supplies and ward off natural disasters in the uMngeni River catchment area. This shift toward an integrated “socioecological systems approach” to managing water, biodiversity, climate, and poverty challenges required the leadership of the (then) head of the Water and Sanitation Unit. Aligning adaptation and biodiversity agendas has helped the city’s environmental champions to become early adopters of climate adaptation and effective defenders of biodiversity. An outcome is the Durban Metropolitan Open Space System (D’MOSS), which created a 94,000-hectare nature reserve to protect biodiversity and ecosystem services.¹⁸³

Durban has explored the synergies between adaptation and mitigation. For example, it initiated three large-scale community reforestation projects to offset the carbon footprints of the FIFA Football World Cup™ in 2010 and COP17-CMP7 in 2011. These projects have created new carbon sinks and delivered multiple adaptation cobenefits by enhancing biodiversity and supplying ecosystem services such as clean water and air. The socioeconomic cobenefits of these projects (such as job creation) are particularly important in encouraging and sustaining local climate action.¹⁸⁴

4. ENABLERS OF TRANSFORMATIVE CLIMATE ADAPTATION IN CITIES

As the examples in Section 3 suggest, preparing for the consequences of climate change will take more than engineered solutions like sea walls. It will take integrated, climate-informed urban planning, policymaking, financing, and community mobilization at the grassroots level. These enabling conditions are essential for cities to pursue transformative climate adaptation, which calls for synergizing the urban adaptation agenda with other pressing priorities, including environmental sustainability, socioecological resilience, and socioeconomic transformation. (see Table 4). Transformative strategies

will include developing city-level early warning systems and clear protocols for community preparedness or moving people and infrastructure out of harm’s way. They will be based on robust partnerships across public, private, and civil society to build support for adaptation and help shape the appropriate regulations, incentives, and assessment criteria. Finally, in the interest of equity and justice, it will be important to raise citizens’ awareness and promote rights-based approaches to change behaviors and policies.

4.1. Strong Leadership

Mainstreaming adaptation into development at the urban scale is not only a planning challenge, but also a governance challenge.¹⁸⁵ The ultimate outcome of mainstreaming is a local-level development plan that anticipates future climate crises while also tackling

TABLE 4 Key Enabling Conditions for Transformative Climate Adaptation in Cities

KEY ENABLING CONDITIONS	DETAILS
Strong leadership	Knowledgeable and visible issue leaders in local government, community-based organizations, or the scientific community can help raise awareness and advocate for resources and capacity. They can drive collaborative action across multiple levels of government and jurisdictions.
Inclusion and equity	Adaptation plans and actions must address historic inequities and varying degrees of vulnerability across cities by including marginalized communities in decision-making; distributing future losses and benefits in fair and equitable ways; and recognizing nondominant cultures, values, interests, and norms in determining which actions to take.
Finance and local capacity	Adaptation plans can support and pool resources from public finance (including intergovernmental transfers), private investments, multilateral support, and local/community-based financing. A combination of these sources can then help target the costs and demands of transformative adaptation by improving infrastructure; alleviating poverty; protecting human health and the environment; and building dedicated skills and capacity across public, private, and civil society organizations. These actions can be further supported by new actors, such as insurance/reinsurance providers or philanthropic entities.
Synergies across scales	Adaptation priorities should align with global priorities, such as those set out by the Sustainable Development Goals (SDGs), Paris Agreement, the New Urban Agenda (UN-Habitat III), Sendai Framework for Disaster Risk Management, and others. This will help attract resource/capacity support, increase knowledge and awareness, and draw attention to the need for fairness in transformative adaptation.
Knowledge, data, and partnerships	Meaningful, localized information and empirical evidence must be available to decision-makers across scales and partnerships to enhance the adoption and spread of new ideas and practices. Partnerships and city-to-city peer exchanges can help scale up good practices.
Evaluation and learning	Emerging technologies make it easier to launch, monitor, and share information about climate adaptation projects. Evaluating outcomes in a participatory and inclusive way is critical for drawing and comparing lessons across cases, understanding the conditions under which specific actions work, and assessing the impacts on different socioeconomic groups.
Accountable institutions and governance	Strong, accountable, informed, and equitable institutions can translate scientific data into appropriate actions, matching adaptation to local needs; ensuring democratic decision-making; and promoting financial, social, and political accountability. Institutions can also work across mandates to promote integration.

Source: Authors’ synthesis.

the underlying structural factors that make the city vulnerable.¹⁸⁶ Strong leadership can support the integration of adaptation into development, which can further streamline decision-making and reduce future remedial costs.¹⁸⁷

Urban climate adaptation leadership requires the ability to build linkages across sectors, scales, and stakeholders.¹⁸⁸ Adaptation leaders need a mindset that embraces uncertainty. Such a perspective leads to an exploration of measures that promote flexibility and allow for adjustment, recognizing that knowledge and understanding will evolve.¹⁸⁹ Climate leaders also help sensitize others to this mindset, promoting adaptive approaches that strengthen systems and institutions, rather than planning and designing for a specific set of climatic conditions. Many of the skills and sensibilities needed fall outside standard silos and areas of expertise. They call upon the facility to think and work in an interdisciplinary and multidisciplinary style. In addition to connecting the dots between city departments, areas of the city, and sectors, leadership must examine the diversity of interests, realities, and experiences in the context of uneven socioeconomic factors, demographics, and adaptive capacity.¹⁹⁰

Leadership from different spheres within a city can help capture diverse needs and opportunities while also supporting a long-term adaptation agenda.¹⁹¹ Political leadership and agendas change with election cycles, so it is important to have steady leadership coming from civil society and research institutions. This can ensure that the knowledge—of vulnerabilities and priorities, of what work has been carried out and how to continue it—does not get lost in a government shuffle.¹⁹² Advocates for inclusive and equitable climate adaptation can play an essential role as well, since climate change and adaptation actions can distribute costs and benefits unevenly, and disproportionately affect marginalized and poor communities. Leadership from business and industrial sectors of a city can help build an agenda promoting long-term economic health. In Surat, India, a city regularly battered by floods, the local Chamber of Commerce emerged as an important advocate for climate resilience.¹⁹³ These examples highlight how government can provide important enabling forces for action, like policy and finance, but that it is not the sole repository of knowledge or catalyst for action.

4.2. Accountable Institutions and Governance

Climate adaptation requires engagement from a range of institutional actors in a city. Our definition of institutions includes formal and informal institutions, as well as explicit and implicit standards and norms.¹⁹⁴ The definition also includes the organizational structures that play a role in creating and enforcing these rules and norms. Institutions can create the enabling environment for adaptation through incentives, guidelines, and protocols that promote resilience and adaptive measures.¹⁹⁵ Alternatively, they can constrain adaptation or promote maladaptation through policies and practices that perpetuate development by exacerbating risk, only protecting individual or elite interests, or undervaluing public goods.¹⁹⁶ Institutions also affect—positively or negatively—the capacities of vulnerable and marginalized groups.¹⁹⁷

As noted in Section 3, local governments that have begun adaptation planning tend to formalize this process within their jurisdiction, which helps to legitimize, facilitate, and coordinate projects across sectors and departments.¹⁹⁸ Some do this by setting up dedicated urban climate units and programs and drafting regulations, policies, and codes.¹⁹⁹ These institutions provide formal guidelines and norms that enhance predictability, establish order, and promote coordination.²⁰⁰ Conversely, there are bottom-up practices, such as community-based adaptation, that involve participatory approaches.²⁰¹ These approaches often target poor communities and are emerging as a means for promoting engagement in assessments, fostering community self-reliance, and raising awareness of climate vulnerability.²⁰²

Cities are arenas for deliberating both the process and substance of climate change needs and potential interventions. Since different urban actors frame the challenge differently, cities must reconcile divergent interests and ideals, as well as opportunities and constraints to action. Building climate resilience requires extensive interaction and collaboration among public, private, and civil society stakeholders. Multiple agencies at various levels of government and numerous private or civil society actors typically need to be at the table to devise effective climate change strategies that respond to challenges that transcend traditional jurisdictional

boundaries. While existing institutional arrangements can provide guidelines, new relationships and arrangements that bridge institutions and foster wider consensus are required for effective and accountable adaptation actions. The case study from the Netherlands provides a good example of this (see Box 10).

More resilient and adaptive cities will need policies and practices that morph and evolve as needed, adjusting to both anticipated and even unanticipated changes. The concept of adaptive urban governance emphasizes the need for a governance structure that goes beyond formal planning and state regulation; one that creates mechanisms to bring together formal and informal rule systems, social learning, and continuous feedback cycles.²⁰⁴ This calls for a paradigm shift in adaptation governance from the focus on physical systems and infrastructure to the development of more integrated workplans across sectors and jurisdictions.²⁰⁵ Boyd and Juhola²⁰⁶ define adaptive governance as decision-making that brings together formal and informal institutions, all relevant stakeholders and social networks that can adapt in the face of uncertainty. This calls for integrating scientific expertise and the knowledge and experiences of local people at risk, and building in opportunities to revise strategies and change course based on feedback and data provided in part by intended beneficiaries of adaptation actions.

Local governments establish standards and codes around climate change, and distribute financial resources from state and national pools and, in some rare instances, from international finance institutions. However, in the face of equity and other considerations, government alone is not equipped to advance adaptation. The case study from Santiago, Chile, illustrates how different regional departments and agencies can work together (see Box 11). In contexts where poverty is criminalized (formally or informally), or where rights and entitlement systems exclude certain populations or are difficult to access, or where powerful vested interests hold sway over government, community-based and civil society organizations can offer an important counterweight in the negotiation of policies, practices, and customs.

City governments therefore need a range of partners to inform and support climate adaptation. Community and civil society organizations and movements that organize

BOX 10

CASE: Management of Deltas and Polders in the Netherlands

The Dutch approach to water management has been evolving since the 7th century to the 21st century. It has gone from natural to defensive to offensive to manipulative. An intensive engineering project—the Deltaworks—installed a network of dams, dikes, levees, and storm surge barriers, but did not stop river flooding from snow melt. So planners took a new tack in 2006, launching the “Room for River” program, widening rivers using “de-engineering” measures to accommodate natural fluctuations.²⁰³ The transition involved “hard” measures (changing the land) and “soft” measures (sociocultural water acceptance). Instead of continuing complex, costly, and risky measures to tame nature, this new approach included building floating homes. This shows how it is possible to avoid lock-in and identify windows for change.

and direct social capital can advance inclusive climate adaptation and demand accountability. Universities and think tanks can play a key role in providing locally relevant climate information, vulnerability and capacity assessments, and adaptation options. Nongovernmental actors are important for ensuring continuity of adaptation efforts in light of political cycles and the changes that can result. Even if election results stall political momentum, mission-driven nongovernmental institutions and knowledge centers have a particularly important role to play in finding new pathways to bring about change.

The uncertainty and complexity surrounding climate change and the many choices available to decision-makers²¹³ will require agile, flexible, and robust solutions that succeed over a range of potential climate scenarios. Comparing scenarios, evaluating trade-offs, and using multimetric valuation can all help weigh choices, according to both outcomes-based and process-based criteria.²¹⁴ Adaptive management and iterative decision-making requires ready access to credible, meaningful information for gauging risk, vulnerability, and adaptation options.²¹⁵

BOX 11**CASE: Integrated Adaptation Planning in Santiago, Chile**

The Metropolitan Region of Santiago de Chile is vulnerable to natural hazards, water scarcity, and insecure energy supply. Political fragmentation has hobbled adaptation in the past, but recent developments have made the city ripe for adaptation action. These include changes in leadership, participation in transnational networks, and growing recognition that climate goals should be integrated into existing development policy agendas.

Between 2009 and 2012, Santiago benefited from the Climate Adaptation Santiago (CAS) project, which was funded by the German government and coordinated by the Helmholtz Centre for Environmental Research (UFZ). The regional government of the Metropolitan Region of Santiago de Chile and the regional secretary of the Ministry of the Environment together supported a diverse, interdisciplinary approach to adaptation. The project helped experts and decision-makers across disciplines exchange “usable” and relevant information about climate science, which improved their capacity to respond effectively. This exchange of information then helped to bridge sectoral gaps and integrate strategies. The subsequent Regional Climate Change Adaptation Plan for the Metropolitan Region helped to strategically direct regional planning authorities, and steer associated finances and capacities toward more integrated adaptation responses.

Assessments of Santiago’s experience highlight the complexities involved in the following: making the case for integrated adaptation planning; communicating scientific data effectively and being clear about methodologies and uncertainties; and ensuring a coordinated response that does not devolve into sectoral fragmentation. They find that a participatory approach can strengthen procedural legitimacy, social capacity, and intersectoral cooperation to help Santiago and other large Latin American cities prepare for the impacts of climate change.

BOX 12**CASE: Facilitating New Arenas of Decision-Making in Surat, India**

Surat, India, offers an example of institutional coordination to stem the risk of flooding in this low-lying and riparian industrial city in the state of Gujarat. Flooding in 2006 left 75 percent of Surat underwater, causing major economic and other losses. The flooding was caused by an emergency release from an upstream reservoir, the Ukai. Situated in a zone with variable rainfall, the reservoir is managed to maximize water available for hydropower, and irrigation to help meet the summer needs of farmers.²¹⁹

Around 2010, the city began a process that strengthened understanding of how more intensive periods of projected rainfall due to climate change would magnify the risk of floods. The municipal authority decided to invest in an end-to-end early warning system, including last mile communication via SMS and other mechanisms throughout the city. The system included more rainfall monitoring in the upper catchment and advances in hydrologic and hydraulic modeling to better evaluate rainfall on the streams feeding the reservoirs, water released from dams, and impacts on downstream communities. The city also took steps to integrate different sources of information and models. Together, these measures widened the window of advance warning from less than one day to as much as four days, expanding options for residents, businesses, and community and relief organizations to plan and prepare.²²⁰

Central to the success of this intervention was the establishment of a new institutional coordination mechanism—the Surat Climate Change Trust—which ensured regular sharing of information while also establishing decision-making protocols among downstream city officials, state disaster management authorities, the national agency charged with dam management, the irrigation department, and the meteorological department.²²¹

Advancements in technology and improved forecasting and monitoring can support decision-making processes. Case studies from Santiago and Surat highlight how cities can channel emerging scientific information to support local decision-making around adaptation.

Solid scientific and technical inputs are valuable, but these alone do not guarantee better decisions.²¹⁶ Cities need clear channels of communication, protocols, and lines of responsibility that connect government authorities and inhabitants, as the risk of elite capture or corruption is especially high. Relevant institutions and stakeholders must also be willing to act on the information that emerges.²¹⁷ Many cities have responded to this need by striving to make decision-making processes more inclusive and adaptable. The Surat Climate Change Trust, described in Box 12, is a good example of this. Sector-specific measures are also needed to strengthen resilience in domains such as public health, solid waste, and emergency management (see Sections 3.2.2 and 3.3.1). Institutional partners must collaborate to realign incentives, mandates, reporting lines, and finance flows to respond to the interdisciplinary and multidisciplinary nature of climate change.²¹⁸ We revisit the idea of inclusive decision-making in Section 4.3.

How local institutions engage and share information on climate adaptation can strengthen or limit resilience-building efforts and provide important lessons for initiating and sustaining adaptation actions in other peer cities. A model that relies only on outside experts for analysis and recommendations without a process to cultivate understanding, interest, and resonance among the local institutions may generate narrowly helpful outputs, missing a chance to seed more transformative change.

4.3. Inclusion and Equity

A transformative adaptation agenda must contend with not only climate impacts, but also with entrenched political and economic dynamics that contribute to (current and past) inequities.²²² Responding to the uneven impacts of climate change requires processes that bring different knowledge and experience sets together. Otherwise, the needs of poorer and more marginalized groups may be overlooked or eclipsed by interest groups that are more politically powerful and financially connected.²²³ Worse, existing vulnerabilities and risks confronting more excluded



Photo credit: Slum/Shack Dwellers International

populations may even be exacerbated. Engaging diverse sets of actors; seeking out local and indigenous knowledge; and deliberately examining a range of interests, values, and expectations does not just make climate adaptation outcomes more equitable, but is foundational to legitimate decision-making processes.²²⁴

The drive for more decentralized forms of decision-making in cities has led to a proliferation of arenas for public participation and deliberation, especially for addressing scientific complexity and uncertainty.²²⁵ Adequately representing civil society interests in the design, implementation, and monitoring of adaptation interventions is vital, in part because adaptation actions are ultimately interwoven with specific populations and regional vulnerabilities.²²⁶ Engaging communities that have intimate knowledge of the place and a direct stake in impacts make adaptation more effective.²²⁷ Cities must therefore explore new arrangements that allow a much wider range of actors—including low-income and other marginalized and at-risk groups—to actively engage with

adaptation planning (see Box 13). In forthcoming work as part of C40's Inclusive Climate Action Programme, the authors of this paper at the World Resources Institute have helped develop policy design guidelines for cities on making a series of climate adaptation (and mitigation) actions more inclusive.

Various nongovernmental organizations (NGOs), foundations, aid agencies, research bodies, and partnership networks have also stepped in to support local adaptation planning.²³⁰ For example, a number of NGOs, such as Mercy Corps in Indonesia and ActionAid in Bangladesh, are facilitating community-based adaptation through community awareness and empowerment programs. Similarly, the Institute for Social Environmental Transition (ISET) and TARU-Leading Edge are conducting urban climate impact and vulnerability studies and helping to draft city climate resilience strategies in Vietnam and India, respectively. The diversity of actors strengthens the legitimacy and sustainability of adaptation processes.²³¹

Different interests, reference points, and value systems can make broadening dialogue challenging.²³² Effective participation also depends upon the capabilities of individual actors. Power imbalances, cultural differences, and gender and minority discrimination make it impossible for marginalized communities to effectively convey

their views. As a result, their participation can amount to little more than checking off a box. Typically their role is restricted to identifying vulnerabilities.²³³ However, urban adaptation presents an array of opportunities to reexamine and remedy structural injustices and the habits and practices that cement them in place.²³⁴ Effective participation in adaptation processes means moving beyond tokenistic inclusion and empowering multiple voices to be heard and valued.²³⁵ This can be achieved by including vulnerable groups, such as women and youth, at all stages with effective mechanisms to develop their capabilities, prioritize their needs, and incorporate different sources of knowledge.²³⁶ Adaptation measures should support daily livelihoods of vulnerable groups and should not reinforce existing inequities and injustices.²³⁷ Table 5 highlights some key criteria for enabling more inclusive and equitable adaptation.

Climate actions should have equitable outcomes, along with broadly inclusive processes that educate elected officials, the public, and the business community about risks.²³⁸ Some scholarship suggests that targeted political mobilization organized by powerful elites and advocacy groups is often more influential in addressing climate change concerns than broad participatory processes.²³⁹ The issue of who has power over the process is critical because it ultimately shapes the way climate change

BOX 13

CASE: Developing Partnerships with Slum/Shack Dwellers International

A recent study from Slum/Shack Dwellers International (SDI) illustrates the role of community-gathered data for urban resilience and inclusion.²²⁸ According to this study, many existing development indicators fail to capture the complex and locally specific conditions of slums. They therefore lead to policies and programs that do not respond to the most pressing needs of the urban poor and can direct investments away from realistic and affordable improvements. Without accurate information and a deeper understanding of the needs and priorities of informal settlements, slum dwellers remain invisible, and efforts to reduce urban poverty and inequality will fail.

To remedy this problem, SDI's Know Your City program (2018) facilitated processes to provide the detailed information needed to reframe adaptation issues from a local perspective and identify practical solutions for informal settlements.²²⁹ The central role of slum dwellers in collecting and processing data, such as on demographics, risks, and access to basic services, ensures a focus on the poor and on operational knowledge for local actors working to implement global commitments. As a result, several cities, like Durban, have partnered with SDI federations to codevelop adaptation plans and institutionalize participatory mechanisms.

TABLE 5

Criteria for Achieving Inclusive and Equitable Climate Adaptation in Cities

CRITERIA	DESCRIPTION
Procedural inclusion through participation	To widen participation in adaptation planning, design, and implementation stages. To recognize differential power in processes and achieve full representation of all interests, values, and norms.
Equitable distribution of losses and benefits	To achieve fair and equitable distribution of potential adaptation benefits and losses across space and time and across communities. To recognize historic inequities, rights, and responsibilities when delineating future adaptation benefits.
Empowerment and capability enhancement	To amplify the voices of historically disenfranchised, marginalized, and vulnerable populations, including women, ethnic minorities, youth, and the elderly. To facilitate mobilization and knowledge-sharing through social networks/capital.
Recognition of less dominant identities and cultural frames	To respect traditional knowledge in decision-making. To address the implications of informality, different intersectionalities, class, identity, and other cultural inequities, as well as the values of the nonhuman.
Recognition of intergenerational interests	To achieve inclusive and equitable adaptation solutions across time, taking into account intergenerational interests and cascading/compounding risks. To avoid adaptation lock-ins, unjust development pathways, and account for the vulnerabilities and rights of future generations.

Source: Authors' synthesis.

priorities enter the public consciousness.²⁴⁰ For example, climate change planning in Santiago, Chile, was led by scientific and technical experts from external development aid agencies and consulting firms.²⁴¹ Similarly, large transnational engineering firms based outside the country guided much of the decision-making around the construction of large-scale climate infrastructure in Jakarta, Indonesia. In both cases, external economic and political interests dominated the discourse, and although climate concerns were ostensibly integrated into the urban development agenda, most local socioeconomic priorities—particularly those concerning vulnerable social groups—were neglected in the process, leading to housing and employment displacement.²⁴²

Even in contexts where there is more transparency, accountability, and “good governance,” decision-making may not be structured to accommodate the iterative, adaptive, and learning-oriented processes that inclusive climate adaptation demands.²⁴³ Furthermore, the systems and processes of the city—as well as the capacities that have been cultivated over time—may be modeled on postcolonial conditions.²⁴⁴ Without fundamental shifts that disrupt existing sociopolitical dynamics and the balance of power, climate adaptation may perpetuate unequal development patterns and norms. Adaptation actions may

lead to conflicts around green/climate gentrification and displacement. For example, the construction of sea walls can displace fishing communities or transfer flood risks to nearby coastal regions.

4.4. Finance and Local Capacity

Public investment in adaptation can generate significant value—instead of just averting losses—and pay for itself. Because cities are engines that power economies, protecting urban economic assets and building resilience to climate change may yield positive impacts, not only within the local and national contexts, but even at the global scale.²⁴⁵ In coastal cities, for instance, the annual cost of global adaptation is only one-tenth the total cost of no action.²⁴⁶ However, cities' ability to access finance for adaptation is constrained, particularly for underresourced cities that do not meet creditworthiness requirements or lack access to national and regional funding streams and capital markets. Furthermore, given the limited fiscal authority of many cities, more concessional financing is needed, with greater coordination across international financial institutions to reduce transaction costs for cities. Partnerships in technical assistance play an important role; for instance, project preparation facilities by NGOs and other agencies have helped governments design

adaptation initiatives as a well-sequenced bankable portfolio of projects.²⁴⁷ While there are limitations to the resources that cities can access for adaptation and resilience building, Table 6 provides a summary of potential financial sources to support urban climate adaptation, while recognizing that different cities have different fiscal powers and sources of finance they can access.

The emerging scholarship on adaptation finance underscores conceptual tensions between adaptation and development finance. Allocating adaptation resources and mainstreaming adaptation objectives within existing bilateral and multilateral finance mechanisms is not easy.²⁴⁹ Prevailing institutional arrangements that guide donor assistance separate external aid flows for adaptation from those earmarked for development. Klein explains three worries that developing countries have

about integrating adaptation finance with development finance: First, developing countries are concerned that mainstreaming could limit adaptation finance as funds get absorbed into fixed official development assistance (ODA) budgets. Second, mainstreaming could divert adaptation funds into more general development activities and reduce the opportunities to evaluate adaptation funding on its own terms. Finally, developing countries are concerned that donor countries could use mainstreaming to impose restrictive conditionalities on adaptation funding.²⁵⁰

A second tension concerns variations in the potential of governments, private actors, and multilateral financing institutions to mobilize additional adaptation funds separate from existing ODA pledges and targets.²⁵¹ Beyond dedicated sources such as those provided by the Adaptation Fund, governments may find it difficult to

TABLE 6 Potential Revenue Sources to Support Climate Adaptation in Cities

ACTOR	SOURCE OF FINANCE	EXAMPLES OF ADAPTATION ACTION
Municipal	Central budget allocations, property taxes, user charges, tourism taxes/fees, impact fees, betterment levies, land value capture, vehicle taxes, licenses/registrations	<ul style="list-style-type: none"> • Maintain infrastructure assets and retrofit small capital investments • Set rates to cover differential costs of adaptation expenditures • Cover cost of incremental extension or upgrading of infrastructure and services • Cover personnel costs for research and advisory services
Intergovernmental	Earmarked grants, conditional grants, shared taxes, programmatic transfers, revenue sharing	<ul style="list-style-type: none"> • Tie grants to programs and give cities flexibility to decide how to spend funds • Make grant disbursement conditional on reforms to local public administration and adaptation policy, programs, and expenditures
Multilateral	International donor funds, official development assistance (ODA), humanitarian aid, technical and capacity support	<ul style="list-style-type: none"> • Provide concessional loans through national and/or regional governments for local infrastructure and service delivery improvements • Provide direct technical assistance to city governments to mainstream climate adaptation in urban planning and/or project preparation • Lend support during and after climate/disaster emergencies for rebuilding and rehabilitation
Private	Municipal bonds, loans, private investments, insurance/reinsurance, individual private capital, pooled finances from communities	<ul style="list-style-type: none"> • Support private investment or public-private partnerships in local adaptation services • Provide long-term finance for green infrastructure • Generate income for larger-scale investments in infrastructure and building-scale adaptation • Fund household and/or community investments in adaptation measures, like housing upgrades to reduce flood and storm risk
Nonprofit	Philanthropy, individual donations, microfinance	<ul style="list-style-type: none"> • Solicit donations for targeted urban adaptation capacity programs for local officials and communities • Cover costs of future welfare losses from weather or other climate-related events • Build local capacity across urban stakeholders to adapt to climate change

Source: Authors' analysis, based on Cook and Chu 2018.²⁴⁸

identify funding sources from their general development budgets that match specific future adaptation needs. To address this, one approach focuses on the adequacy, predictability, and “additionality” of funds.²⁵² Another approach distinguishes funding instruments according to whether or not a market-based alternative is possible for the particular intervention.²⁵³ For instance, value capture, structured finance, and risk-based instruments like reinsurance or catastrophe bonds can be tailored to account for discrete adaptation responses in specific urban assets or areas.²⁵⁴ ODA, on the other hand, might be necessary when no such market-based proposition can be developed in advance, either because markets are less mature or because solely market-based responses are insufficient. Valuing risk and adaptation in financial decisions can demonstrate that more climate-responsive cities are more financially attractive. However, this can lead to further socioeconomic marginalization and exclusion of poor, underrepresented sections of society due to their inability to pay for adaptation services or their exclusion from the “formal” urban economy.

The implications of specific revenue flows extend beyond closing the financial gap to issues of transparency, accountability, and equity for vulnerable populations.²⁵⁵ Despite growing complexity in the global structure for financing adaptation, it operates without established rules and norms to ensure the inclusion of local institutions or vulnerable populations in investment decisions.²⁵⁶ As local governments gain experience utilizing different financial resources for adaptation, more studies are needed to examine how different public and private financial instruments influence patterns of local governance. For instance, domestic tax revenue might fall short of demand for urban adaptation investment, but taxation can often lead to better governance by enhancing administrative capabilities and increasing accountability.²⁵⁷ Another important question concerns how to design and implement investments in adaptation in the global South where regulatory frameworks for urban finance are incomplete or nonexistent.²⁵⁸ Domestic capital markets could contribute significant adaptation resources, but capital markets for urban infrastructure in many vulnerable countries have been slow to develop.²⁵⁹ In these contexts, this can be an opportunity to develop new financial regulations that incorporate climate adaptation considerations.

Uncertainties over climate impacts and the cross-sectoral nature of many adaptation options can make it difficult to promise private financiers what they typically want from their investments, that is, low transaction costs or the ability of the asset to produce dedicated streams of revenue. Cities should work with the commercial development industry to find ways to generate local financing for adaptation investments. Higher-income cities will need more sophisticated taxation and value-capture measures with relevant insurance schemes. Lower-income cities must strengthen land management systems and invest strategically in resilient infrastructure for greater returns. As climate-related risks and potential losses grow faster than the pace of private financial flows and official development assistance, public finance can and will only serve as a bridge between multilateral/national financial sources and community-based finance.

A multiscale perspective to climate adaptation in cities allows one to move from capacity building to capacity exchange, drawing valuable lessons from effective micro-level adaptations in cities of different sizes. This would undoubtedly lead to more innovative resource mobilization and models of success. More innovative financing and resourcing models for climate adaptation could bridge investments between vulnerable communities and local governments. For example, for more well-resourced countries, national development banks can support adaptation investments in cities. Concessional financing may also be required given differences in the fiscal powers, financial maturity, and creditworthiness of cities. Partnerships in technical assistance play a supportive and growing role, while coordinated action by multilateral financial institutions can help reduce transaction costs for cities. Finally, one could embrace multiple technologies and build synergies for inclusive, sustainable urban development.

As stated earlier, smaller and medium-size cities must build the capacity to access and manage donor resources. Rather than focusing narrowly on “hard” infrastructure that responds to certain hazards, urban finance systems should be flexible and responsive to enable holistic policymaking. Adaptation investment is most needed in poor neighborhoods and low-income cities in the global South. These areas typically have limited access to finance that could enable investment in adaptive development.²⁶⁰

Urban residents in low-income areas already suffer from poor public services and government neglect. Informal settlement residents may lack a legal address, which means they cannot open a bank account, obtain insurance, or connect to utilities.²⁶¹ The “business case” alone should not drive climate adaptation actions. Instead, these should be seen as a public good for a stable, well-functioning, and fair society. Climate adaptation should be a normative collective position that appreciates diverse coping capacities, recognizes the urgency of climate change, and supports the security of all.

Financing climate resilience projects hinges on a ready pipeline of viable projects. Project preparation and development more broadly—beyond climate change—is a constraint for many cities and countries and a result of capacity limitations. In 2007, this prompted the establishment of Cities Development Initiative in Asia (CDIA), an arrangement designed to help fill gaps in infrastructure development and financing for the region.²⁶⁴ Even limited finances can support important soft measures to build resilience.

Financial management skills are required on the part of national and city governments, including in some cases a track record of successful budget and project management and a solid credit history. Cities need political connections and networks to open doors, even to get on the radar of decision-makers who hold the purse strings. This constellation of forces means that smaller cities and towns tend to rank lower in terms of prioritization of resources. Their limited capacity to tackle adaptation and resilience building and to handle the administrative demands of managing projects from the larger funders perpetuates a cycle that directs opportunity away from them and toward a certain class of cities, regardless of need. At the same time, the integration of adaptation priorities across scales can help ensure that a series of smaller development-oriented investments at the local level aggregate toward larger adaptation benefits and more transformative action (see Box 14).

Finally, upstream decision-makers and program and project designers need a better understanding of climate resilience and adaptation. When the donor agencies and ministries

BOX 14

CASE: Multilevel Coordination of Adaptation Finance in Copenhagen, Denmark

In 2012, the government of Denmark released a new framework in its climate action plan to better integrate adaptation across municipalities, utilities, and government agencies. The Ministry of the Environment amended the Planning Act to require all 98 municipalities in the country to carry out a risk assessment and integrate municipal-level climate adaptation plans directly into local development plans within two years. The central government provided guidance to harmonize planning and investment decisions and support partnerships across city agencies, utility companies, and national ministries. The central government and municipalities also agreed that municipalities should increase adaptation-related investments in wastewater treatment by DKr 2.5 billion (approximately US\$445 million) in 2013.²⁶³ In parallel, wastewater utilities were tasked with preparing risk assessments for flooding scenarios, the Ministry of Defense was told to adjust reporting systems for emergency response efforts, and the Ministry of Transport planned to publish guidebooks for coastal areas and was also directed to map road and rail network locations at risk for flooding.

Denmark’s approach demonstrates a strong emphasis on vertical and horizontal coordination across agencies and stakeholders. The central government successfully provided guidance to help municipalities map risks and integrate with local strategies, while increasing the knowledge base across other national agencies and utilities. The central government also set timelines for evaluating actions, created financing mechanisms for utilities, and engaged private enterprises to contribute to new climate adaptation innovations.

of finance in recipient countries have a limited grasp of these challenges, this limits the options available for action. Inside development banks, many of the loan officers and technical assistance providers do not have adequate training in concepts of resilience and integrated urban systems, and in how to advance effective and equitable adaptation measures. Vestiges of “predict and act” inform some of the responses, resulting in mindsets focused only on “climate proofing” infrastructure, rather than considering how to design interventions that can realize multiple benefits. Such multiple-outcome interventions require a different approach to program design and often a different way to allocate resources. Current institutional structures and incentives make coordination, budget sharing, and other approaches that foster cross-unit collaboration and joint problem-solving seem more risky and costly than advantageous.

4.5. Knowledge, Data, and Partnerships

Relevant, meaningful information and technology must be readily available across scales.²⁶⁵ But decision-makers also need technical capacity and a pathway to learn and use scientific information. They need institutions or individuals who can interpret and present it in ways that makes sense, and frame and apply it in ways that are relevant and appropriate for each context. Also needed are institutions with a mandate and a mission to use scientific data, information, protocols, and practices, and the capacity to take action. Where resources (including time and money) are scarce, and institutional capacities are weak, it becomes harder to learn and make use of new data and information.

Numerous networks have emerged to bridge and fill the myriad resource and capacity gaps around adaptation action in cities.²⁶⁶ Key players include the Rockefeller Foundation–funded 100 Resilient Cities, ICLEI–Local Governments for Sustainability, C40 Cities Climate Leadership Group, and others. They have spearheaded the dissemination of best practices by supporting sectoral pilot projects, recognizing adaptation priorities in municipal budgets, and producing comprehensive downscaled climate projections. Despite the growing importance of networks, their influence is often confined to larger (or “elite”) cities that receive the most international recognition and investment, have the greatest staffing

capacity, and attract the most active and vocal policy entrepreneurs. Networks display this membership bias because they themselves have an incentive to emphasize their accomplishments, earn praise, and attract resources from the international community. This funnels adaptation knowledge and awareness toward flagship cities and away from small- and medium-size urban areas, particularly across the global South.

Finally, there is a need for horizontal spreading and diffusion of ideas and practices. Peer learning, exchange, and mobilization among urban poor and economically, politically, and socially marginalized groups could be transformative. Pooling and organizing social capital can not only strengthen community resilience, but also shift power relationships.²⁶⁷ To ensure that the approaches taken forward are relevant to the diversity of needs and interests in the city, a legitimate and credible process must meaningfully draw in the diversity of knowledge sets from across the city. Building this engagement, ownership, and championship requires time, capacity, and skillful facilitation.²⁶⁸ This work is a hard, messy, slow slog that is not keeping pace with the scale of need. Cities need innovations and resources to build a cadre of actors to instigate and implement resilience and adaptation everywhere. Cities, especially those with limited resources and autonomy, need policy and financial commitments at national, state, provincial, and international levels. This is particularly true in secondary and tertiary cities in the global South.

4.6. Synergies across Regional, National, and Global Scales

A central feature of climate change action in cities is the political and jurisdictional complexity that shapes urban decision-making and its outcomes. Efforts to forward transformative change in cities must confront the multiple levels and scales at which urban processes are organized.²⁶⁹ As noted earlier, coordinating climate change actions across diverse landscapes and populations is challenging because climate risks and impacts are affected by geography, ecology, culture, laws, politics, and jurisdictional issues.²⁷⁰ Cities are typically embedded within wider governance regimes—with responsibilities divided across different levels of government—so many climate

change actions require collaboration across jurisdictional boundaries. However, the ability to bridge these boundaries requires institutional flexibility and political know-how. For example, climate impacts and disaster risks are shaped by both the way in which urban development unfolds and by broader development policies and practices within a state and nation.²⁷¹

At the global level, international environmental and climate change agreements—such as the Paris Agreement from COP21 in December 2015; Habitat III, the UN Conference on Housing and Sustainable Urban Development; and the Sustainable Development Goals (SDGs)—all have strong bearing on local-level actions.²⁷² Figure 9 illustrates the linkages between urban adaptation and the SDGs. The multiple scales of governance and decision-making add layers of actors, networks, and institutions to any urban adaptation program.²⁷³ The three global agendas of the Paris Agreement, the New Urban Agenda, and the SDGs help pave the way for transformative adaptation in cities. Each cites the transformation possible for cities concentrating on building infrastructure, equity and inclusiveness, and prosperity for all.

4.7. Evaluation and Learning

From a policy standpoint, we are now moving toward assessing and evaluating portfolios of policy and planning tools, as well as comparing collective experiences of opportunities and constraints.²⁷⁴ The ability to monitor climate adaptation projects and evaluate outcomes is a critical ingredient in refining our understanding of what works when, where, and why.²⁷⁵ As climate adaptation is especially new in the urban contexts, these insights could prove invaluable for framing options and evaluating cost-effectiveness. Ideally, both *process* and *outcome* measures are taken into consideration, given the importance of engaging diverse perspectives and stakeholders. In practice, however, monitoring, measurement, and evaluation are tricky, while evaluation results are often not adequately applied to inform future programming. Standard approaches that rely on measuring change against a baseline are especially challenging in the context of climate change, since both baseline and context are shifting.²⁷⁶ The localized nature of impacts and adaptation measures also

make metrics and measurement challenging. Gains and losses in terms of human development and poverty have significant impacts on project outcomes, but may be at least partially distinct from climate change impacts.

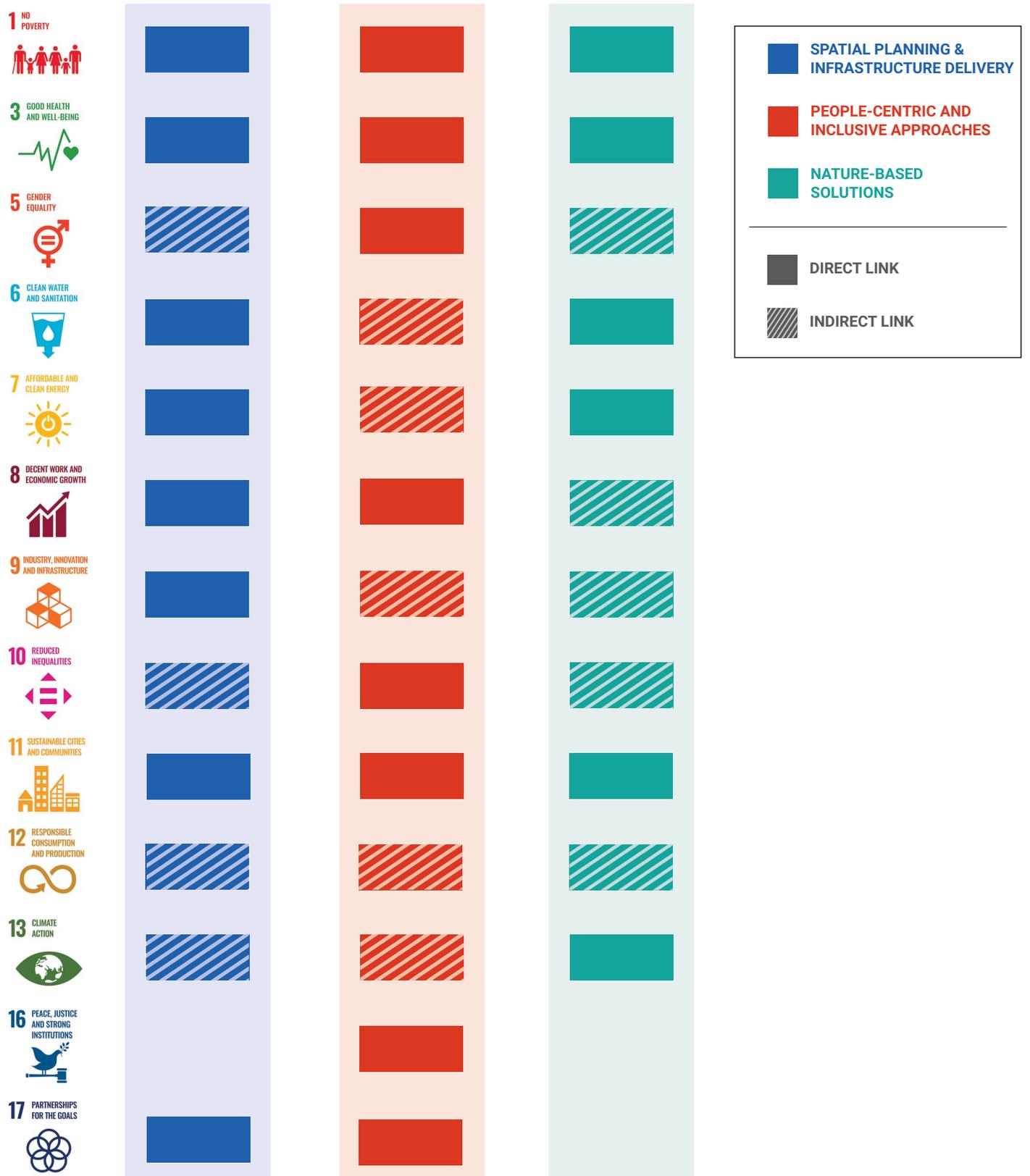
Table 7 illustrates a selection of recent adaptation metrics used in cities. Efforts to measure resilience have picked up momentum in recent years. In 2016, for instance, the Rockefeller Foundation launched the Resilience Measurement Evidence and Learning Community of Practice. Similarly, the Asian Development Bank's Urban Climate Change Resilience Trust Fund (UCCRTF) is focusing on how to measure the benefits of resilience investments. The literature is robust on the importance of iterative decision-making to manage flexibly and in the context of uncertainty. Such an approach requires the ability to review and assess progress. However, there are few approaches that are specifically relevant to urban contexts.²⁷⁷

Documenting individual urban experiences can help illuminate policy levers, strategic planning tools, specific resource and capacity requirements, and particular monitoring and evaluation needs. However, because adaptation action depends on local contexts, generating wider lessons has been difficult. Differences in political economy; resources; and the value of informal, autonomous, or nonstate strategies require further exploration. Adaptation must be investigated as a cross-sectoral issue, linked with emerging mitigation, resilience, and sustainable development priorities to catalyze more comprehensive, transformative pathways for change.

"Risks" covers indicators on risks, threats, hazards, and the impacts of climate change and climate change-related extreme weather events. "Process" includes indicators on the processes of capacity, strategy, and policy development, as well as prioritization of actions. "Progress" includes output, outcome, and performance in the context of institutional change, as well as the action or response depending on the publication. "Impact" can focus on either the direct impact of an intervention, or on the wider impacts of improved risk management; reduced vulnerability, exposure, impacts, and related extreme weather events, as well as increased resilience, transformative capacity, etc.

FIGURE 9

Synergies between Urban Adaptation and the Sustainable Development Goals



Source: Authors' synthesis.

TABLE 7

Frameworks Comprising Adaptation Metrics for Cities

(E = Mainly existing indicators or data, N = Mainly new indicators or data, M = Mix of existing and new indicators or data)

ORGANIZATION	FRAMEWORK	INDICATOR COVERAGE
ARUP / C40	Climate Risk and Adaptation Framework and Taxonomy (CRAFT)	Risk, Progress, and Impact (M)
ARUP / Rockefeller Foundation	City Resilience Index (2018)	Drivers, Vulnerability, Enabling Environment, and "Resilience" Dimensions (M)
C40	Measuring Progress in Urban Climate Adaptation Framework	Process, Progress, and Impact
Covenant of Mayors	Sustainable Energy and Climate Action Template (SECAT)	Process, Vulnerability, Progress, and Impact (M)
ESPON	Climate Change and Territorial Effects on Regions and Local Economies	Drivers, Risks, and potentially Impact (E)
GPSC	Urban Sustainability Framework	Enabling Environment (Process), Outcomes (Progress and Impact) (N)
ICLEI Canada	Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation	Process and Progress (M)
ISET	Indicators of urban climate resilience: A contextual approach	"Resilience elements"
ISO	Indicators for Sustainable Development and Resilience in Cities	Performance on city services and quality of life, and Impact (M)
ND-GAIN	Urban Adaptation Assessment	Risk and Readiness—covers Progress and Impact (E)
RESIN	European Climate Risk Typology	Drivers, Risk, Vulnerability, and potentially Progress (E)
UN-Habitat	City Resilience Profiling Tool	Multistakeholder, people-centered data (E)

Sources: Bours et al. 2013; ARUP and Rockefeller Foundation 2018; Leiter et al. 2019.²⁷⁸

Notes: ESPON = European Observation Network for Territorial Development and Cohesion, GPSC = Global Platform for Sustainable Cities, ICLEI = International Council for Local Environmental Initiatives (now, Local Governments for Sustainability), ISO = International Organization for Standardization, ND-GAIN = Notre Dame Global Adaptation Initiative, RESIN = Climate Resilient Cities and Infrastructures.

5. CONCLUSION AND KEY MESSAGES

This paper analyzed the systemic risks climate change poses for cities and the vulnerable populations within them. Urgent adaptation action is needed in cities to protect critical infrastructure, economically important assets, and ecosystems and people in light of projected climate change impacts. Proactive adaptation measures against temperature change, extreme precipitation, and sea level rise can reduce immediate economic losses and preserve human lives, health, and well-being. Building on this need for urgent action, the paper called for a reorientation toward “transformative adaptation” that is equitable and inclusive and considers climate risks as an integral part of urban planning, development, and decision-making. It focuses on systemic changes to urban development processes, addressing how cities must account for the potential impacts of climate change as they strive to meet urgent needs for core urban infrastructure and services (such as energy, water, sanitation, transportation, land use/spatial planning, and housing), and for employment, health, education, and social amenities. We discussed the enabling conditions for transformative climate adaptation, such as innovations in governance, financing, policy, and planning across urban sectors and scales of government.

Transformative adaptation must harness the interrelationships between the complex systems that make cities work. Many cities have been innovators and early adopters, and we provided evidence that cities across the world are progressing toward adaptation. Local contexts notwithstanding, there are many similarities between cities’ efforts to move along this path. Recent global policy initiatives, including the SDGs and the Paris Agreement, have helped channel financial and human resources into assessing cities’ vulnerabilities. Such assessments have mostly been followed up with plans for adaptation and resilience building. Although we have witnessed incremental adaptation action in cities, we have yet to see exemplars of transformative adaptation, particularly those that address the risk-development nexus, enhancing the city’s resilience and long-term economic productivity, while simultaneously integrating goals of social equity, inclusiveness, and justice.

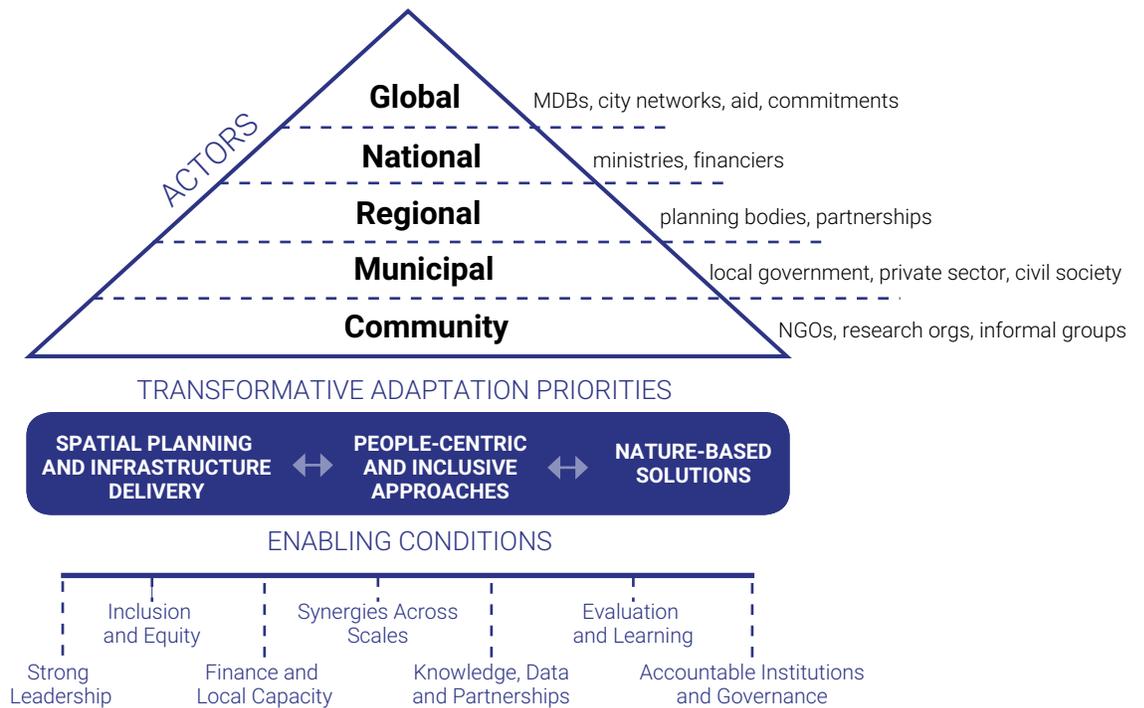
The paper showed that systemically responding to climate vulnerabilities, both within and across cities, and including diverse local interests and values, enhances the potential for transformative change. Holistic risk management strategies are needed in London, New York, Tokyo, and other cities in the global North faced with urban flooding, poor air quality, and heat island effects. These strategies are equally important in cities in the global South, where risks such as sea level rise, extreme weather impacts, and urban inundation loom against a backdrop of development and infrastructure deficits. Further, in emerging economy cities, unplanned urbanization, sprawl, and spreading peri-urban developments are degrading ecosystem services such as forests, watersheds, and open spaces, and threatening agricultural lands, food production systems, and the ecological integrity of the wider region.

For policymakers and practitioners the challenge is to seize new risk management, asset protection, and adaptation opportunities while integrating them into cross-sectoral policy objectives. This must be done while recognizing long-term equity concerns across diverse urban interests that may be conflicting with each other. The needs of marginalized and vulnerable populations should be considered carefully in designing and implementing adaptation plans and distributing their costs and benefits. Figure 10 synthesizes discussions in Sections 3 and 4 by illustrating ways to identify transformative adaptation options in cities. It highlights the major dimensions of such a transformative vision, including the spatial scale (community, city, national, etc.) and main actions needed to achieve innovative adaptation cobenefits. These include spatial and infrastructure planning, people-centric approaches, and nature-based solutions. It also highlights the enabling conditions needed to implement the priorities for transformative adaptation, including accountable institutions and governance, innovative financing, local capacity, scientific data, synergies across scales, and a focus on inclusion and equity.

New and emerging cities are likely to expand rapidly in the coming years.²⁷⁹ They need to integrate transformative adaptation into their plans for building infrastructure, providing services, and promoting development, taking a holistic approach that avoids the mistakes cities have

FIGURE 10

Transformative Adaptation Priorities in Cities with Enabling Conditions and Scales of Decision Making



Source: Authors' synthesis.

Note: Each enabling condition is discussed in detail in Table 8.

made in the past. There is a key window of opportunity to transform the pathways and trajectories of cities that are still emerging or developing. For them, new visions of climate-resilient development are achievable. Finally, emerging innovations in infrastructure, technology, and social service provision can be harnessed in a more decentralized manner. This means enlisting nonstate, informal, indigenous, crowd-sourced, or other community-based sources of knowledge and actors that represent a similar range. Interdependencies between climate risks must become opportunities to take cobeneficial actions that balance adaptation, mitigation, sustainability, resilience, and development concerns. Achieving these synergies effectively through local action is necessary to support more transformative, climate-resilient urban futures.

5.1. Recommendations to Make Progress toward Enabling Conditions

In light of a rising call to action, this section briefly synthesizes the six key messages from the survey of climate adaptation constraints and enablers in cities. Table 8 lists key short- (two to five years), medium- (five to ten years), and long-term (ten years and beyond) recommendations corresponding with the “priority action areas” outlined in Section 5.2.

It is vital to identify the opportunities for advancing synergies and cobenefits between the agendas of mitigation, adaptation, resilience, transition, transformation, and sustainable development. Such agendas should be viewed as advancing along a continuum, where reaching each stage depends on local

TABLE 8 Key Recommendations for Transformative Adaptation Action in Cities (with time scales)

ENABLING CONDITIONS	RECOMMENDATIONS TO MAKE PROGRESS	TIME SCALES
Strong leadership	<ul style="list-style-type: none"> Nurture political leaders, knowledge entrepreneurs, and social movements that can raise awareness and advocate for climate adaptation. 	Short/Medium
	<ul style="list-style-type: none"> Reframe current and future urban development trajectories through the “climate lens,” taking into account recent scientific projections and the need for more innovative and inclusive visions of urban futures. 	Medium/Long
	<ul style="list-style-type: none"> Promote transformative resilience thinking in decision-making and planning. 	Medium/Long
Inclusion and equity	<ul style="list-style-type: none"> Prioritize engagement with urban poor, vulnerable, and marginalized stakeholders in climate adaptation planning. 	Short
	<ul style="list-style-type: none"> Design participatory arenas to ensure the coproduction of adaptation solutions between public, private, community-based, informal actors, as well as international experts. 	Short/Medium
	<ul style="list-style-type: none"> Ensure strong community ownership and buy-in to adaptation interventions and resilient development outcomes. 	Short/Medium
	<ul style="list-style-type: none"> Devise parameters to ensure procedural and distributive inclusiveness, social equity, and climate justice. 	Medium/Long
Finance and local capacity	<ul style="list-style-type: none"> Step up financial support for urban adaptation, and ensure international financial institutions, donors, and the private sector prioritize valuing and incentivizing such investments. 	Short
	<ul style="list-style-type: none"> Harness and share the value created from adaptation investments between local governments and private actors, ensuring equitable distribution of benefits across population groups. 	Short
	<ul style="list-style-type: none"> Create funding incentives or commit resources for local engagement and demonstration projects with cross-agency coordination at city level. Design intergovernmental funds that support adaptation planning and action. 	Short
	<ul style="list-style-type: none"> Address and analyze capacity and skills gaps in the context of climate adaptation, risk management, and resilient development at the local level. 	Short
	<ul style="list-style-type: none"> Recognize the “resilience dividend” in the design, prioritization, and implementation of both “soft” and “hard/engineered” adaptation actions. Increase climate-resilient investments and capture value from adaptation benefits. 	Short/Medium
	<ul style="list-style-type: none"> Revisit regulatory frameworks to allow for more effective pooling and steering of public, private, and community-based sources of adaptation finance. 	Short/Medium
	<ul style="list-style-type: none"> Provide training and institutional support to municipal authorities to prevent outsourcing of adaptation planning and to better reflect local priorities. 	Short/Medium
	<ul style="list-style-type: none"> Delineate financial logic and investment criteria for socially responsible, sustainable, and equitable forms of infrastructure and service delivery. 	Short/Medium
	Synergies across regional, national, and global scales	<ul style="list-style-type: none"> Facilitate more comprehensive adaptation strategies by harnessing networks and partnerships with transnational actors, rural districts, nongovernmental organizations (NGOs), and transboundary institutions.
<ul style="list-style-type: none"> Ensure that regional and local adaptation plans build upon major national policies and commitments, particularly in the context of urbanization trajectories; other subnational climate strategies; economic development plans; land use and transportation plans; critical infrastructure policies; and strategic, fiscal, and investment plans. 		Short
<ul style="list-style-type: none"> Support global scientific assessments and toolkits that include city-level knowledge and experiences. 		Short
<ul style="list-style-type: none"> Embed and synchronize adaptation planning within national, regional, and international resource distribution, regulations, and financing strategies through incentives and guidance. 		Short/Medium
<ul style="list-style-type: none"> Offer incentives for sharing knowledge, capacity, and resources across city networks, focusing on South-South collaborations, in particular. 		Short/Medium

TABLE 8 Key Recommendations for Transformative Adaptation Action in Cities (with time scales)

ENABLING CONDITIONS	RECOMMENDATIONS TO MAKE PROGRESS	TIME SCALES
Knowledge, data, and partnerships	• Require and support cross-agency and cross-sectoral knowledge exchange and consultation on urban climate adaptation and resilient development.	Short
	• Foster data and knowledge co-production platforms between city government, civil society and community groups, and research and academic institutions to make climate science and possible adaptation pathways specific to the needs of local decision-makers and users.	Short/Medium
	• Enable multiscalar partnerships, mechanisms for resource transfer, and knowledge communities between cities and global, national, regional, and community-level institutions.	Short/Medium
	• Support long-term science-policy-practitioner coordination with effective citizen communication strategies.	Medium/Long
Evaluation and learning	• Devise and apply inclusive monitoring, assessment, and evaluation metrics for cobeneficial urban adaptation actions.	Short/Medium
	• Facilitate South-North and South-South models of peer learning and evaluation of urban adaptation actions.	Medium
	• Create a global open access repository of data at the city level capturing climatic and socioeconomic variables, thereby generating lessons that can be replicated across scales.	Medium
Accountable institutions and governance	• Ensure and encourage planning for urban adaptation at the national level because many cities depend heavily on national transfers and policies.	Short
	• Break the silos of urban governance and management to incentivize more holistic and multi-jurisdictional spatial planning and policymaking around climate adaptation.	Short
	• Promote autonomy and flexibility in local government policymaking to support more innovative forms of adaptation action.	Short/Medium
	• Develop robust institutional mechanisms to manage potential economic losses and navigate tensions and conflicts in climate adaptation.	Medium
	• Develop governance accountability frameworks to ensure transparency, equity, and inclusivity in climate adaptation.	Medium

Source: Authors' synthesis.

political, governance, and ideological opportunities and barriers. Cities house competing interests and values in their dense mixture of different actors, agendas, and assets. These underlying tensions and conflicts can drive cities along particular development and adaptation pathways, which may or may not be climate transformative. Climate vulnerabilities in cities result from complex intersections of climatic and nonclimatic factors, including the way cities develop. Vying interests exacerbate existing inequities in cities and may force marginalized and poor urban populations to bear the brunt of climate and development impacts. Understanding the multiple linkages between urban planning and climate adaptation action in cities is vital.

There is a need for more locally relevant resource and capacity support. In particular, cities need more local leadership spread across different institutions and agencies (with associated capacity, vision, knowledge, and agency). Skills, training, and support are needed to promote iterative management, cross-sectoral communication, collaboration, and coordination. Cities also need political agency over managerial functions, finance and budgets, and autonomy over sectoral functions to advance identified solutions. Robust metrics are needed for distributing adaptation costs and benefits; responding to damage and lost assets; and gauging how impacts will vary across populations, communities, and types of assets. Local knowledge institutions and intermediaries can help build

this understanding. More scientific capacity is needed to downscale climate models and scenarios to meet local needs. And these must be matched with robust assessments of future urban demographic growth trends, urbanization and development patterns, and “hotspots” of infrastructure need. One must be able to distinguish and map out how both extreme and slow-onset risks will affect different sectors and populations, and analyze factors that contribute to everyday risks and their interactions across time.

We must take non-state, informal, and autonomous or community-led strategies seriously, devising approaches to harness their potential. Neither top-down nor bottom-up solutions alone are enough to ensure that cities are adequately adapting to climate impacts. This is particularly true in cities in the global South, stymied by poor governance, lack of accountability, and resource scarcity. Adaptation must meaningfully engage the range of actors who live in the city, especially those coping with development failures, structural inequality, and climate change. We should enable processes that promote coproduction and shared learning to build an inclusive understanding of the range of impacts in the city. This will help to create a shared vision for the future where priorities and plans reflect not only the wishes of dominant economic, financial, or political interests, but the needs of all constituencies.

From a multiscale perspective, we must recognize cities’ potential to pioneer new alternative strategies, but also realize the limitations of actions solely at the local scale. Policy incentives and institutional enablers at city, state, national, or international levels can promote adaptation across multiple scales (local, district, regional, watershed, and beyond). We must recognize cities and city-regions as laboratories of adaptation experimentation and innovation. Cities are unique spaces to explore opportunities to link climate adaptation and resilience to the SDGs, Sendai Framework, New Urban Agenda, and other global and national development policies. We must further explore the implications of multiple modes of governance—local, collaborative, informal, and multiscale—that can effectively support climate and action in cities. We should also harness opportunities for cities as sites of more globally equitable, resilient, and just development in the context of climate change.



Photo credit: Lubaina Rangwala/WRI.

We need to move beyond documenting single case studies to cross-sectoral and multi-sited analysis to facilitate comparative learning, assessment, and evaluation. As we have shown in this paper, many disparate examples provide important lessons on how cities need to adapt to climate change. Differences between cities can make it challenging to distill lessons and advance relevant and appropriate adaptive measures that can be more universally applied. Therefore, it is important to promote and facilitate learning from practice, advance opportunities for peer exchange at scale, and to build capacities for adaptation where it is needed. Peri-urban communities (on the urban-rural continuum) as well as medium- and small-size local authorities need this support. Building resilience and advancing adaptation also requires a different mindset—shifting from a “predict and act” paradigm to one that can accommodate decision-making in the context of uncertainty. This paradigm demands characteristics such as resilience, flexibility, redundancy, modularity, and the ability to monitor and

track progress. In addition to developing such a monitoring and evaluation framework, cities need a global open access repository of data that captures climatic and socioeconomic variables, as well as new knowledge and information that can be replicated across scales.

Finally, transformative approaches to urban adaptation must recognize the interests, values, and vulnerabilities of historically marginalized communities, include these in decision-making and planning, and distribute the benefits and costs of proposed adaptation interventions in a more fair and equitable manner. Robust mechanisms are needed to handle potential conflicts and identify barriers and enablers to adaptation in urban low-income or informal settlements. Transformation also calls for recognizing existing structural inequalities within cities. This includes ensuring citizenship rights to all socioeconomic groups, giving marginalized people essential social protection and access to basic services, and prioritizing interventions that build adaptive capacity. Finally, we must align incentives across the different users and interests to promote forward-looking measures that build resilience and promote proactive adaptation, recognizing that repairing damage inflicted by climate change is far more costly than taking the steps needed to prevent it.

5.2. Advancing Implementation of High-Priority Adaptation Actions

As discussed in Section 3, the review of literature, study of cases, and consultations with experts and practitioners we undertook for this paper points to three high-priority action areas for urban climate adaptation that can yield some of the largest development dividends. These include spatial planning and infrastructure delivery that is informed by climate risks; prioritizing risk reduction for vulnerable groups; and, finally, nature-based solutions for managing water and heat risks and for ecosystem protection. Table 9 below illustrates the importance of multiscale action and of involving diverse stakeholders, and organizes these high-priority action areas according to the roles that actors of different types, and operating at different scales, may play to advance implementation.

KEY ACTION AREAS			
ROLES OF KEY ACTORS	<p>1. Spatial planning, infrastructure design and delivery informed by climate risks</p> <ul style="list-style-type: none"> Emphasize the role of urban systems as facilitators of climate-resilient development pathways. Integrate adaptation priorities and resilience thinking into current and pipeline development strategies, spatial plans, infrastructure/service designs, financial systems, and social welfare provision schemes. 	<p>2. Prioritize risk reduction for vulnerable groups and those living in informal settlements</p> <ul style="list-style-type: none"> Focus on people-centric, inclusive, and equitable adaptation approaches. Pursue climate change knowledge and action coproduction between public, private, civil society, and informal actors. 	<p>3. Nature-based solutions for managing water-related and heat risks and for ecosystem protection</p> <ul style="list-style-type: none"> Rescale urban boundaries to account for adaptation priorities based on ecosystems, rural-urban landscapes, and regional networks. Uncover cross-sectoral synergies and itemize cobenefits between different sustainable development, human well-being, and ecological priorities.
	Urban/local authorities		
	<ul style="list-style-type: none"> Produce locally grounded climatic models to assess and visualize environmental risks and associated socioeconomic, human, and ecological vulnerabilities. Require and support integrated assessments of climate risks to diagnose different barriers and opportunities to adaptation action. Develop metrics and evaluation indicators on how to design, prioritize, and assess cobeneficial adaptation strategies. Emphasize translating scientific models and assessments into general planning, management, and regulatory functions. 	<ul style="list-style-type: none"> Articulate approaches toward community-based vulnerability and adaptation needs assessments within formal development strategies. Form broad consultative and participatory arenas to coproduce potential cobeneficial actions. Focus on informality. Prioritize the adaptation requirements of informal settlement dwellers, design adequate social security schemes that build adaptive capacity. 	<ul style="list-style-type: none"> Support cross-departmental coordination, resource support, and capacity development, including identifying strategic opportunities to advance multiple outcomes. Establish dedicated funding pathways to channel external resources to local adaptation measures, including investment in nature-based solutions. Collaborate with financial institutions and private firms to develop creative and innovative approaches to fund/ finance nature-based solutions. Offer policy and regulatory frameworks and incentives for floodplain restoration and watershed protection. Support knowledge coproduction through stakeholder engagement platforms to identify equitable processes and terms for managed retreat and restoration of floodplains and coastal zones subject to sea level rise. Proactively anticipate and design policy mechanisms to avoid fostering “green gentrification,” and economic and cultural displacement as by-products of investment in green infrastructure.

KEY ACTION AREAS		
1. Spatial planning, infrastructure design and delivery informed by climate risks (continued)	2. Prioritize risk reduction for vulnerable groups and those living in informal settlements (continued)	3. Nature-based solutions for managing water-related and heat risks and for ecosystem protection (continued)
National/regional authorities		
<ul style="list-style-type: none"> • Support transboundary and multilevel assessments of climatic risks and establish corresponding institutional bodies to design adaptation strategies that span ecosystems, rural-urban landscapes, formal-informal institutions, and regional political economic networks. • Develop national policy or legislation mandating climate-informed planning. Identify clusters of cities (or city-regions) based on adaptation needs, creating tiered and phased action plans at regional and local levels. • Develop guidance on metrics and evaluation indicators for cobeneficial adaptation strategies for use by localities and transboundary institutions. • Devolve and decentralize governing powers to increase autonomy of urban authorities. • Ensure adequate funding to urban authorities and support bottom-up adaptation. • Offer resources for conflict management and mediation in the event of contentious proposals. 	<ul style="list-style-type: none"> • Support knowledge coproduction through the creation of multiple stakeholder engagement platforms. • Enable the participation of rural and peri-urban communities in articulating adaptation options that protect livelihoods and security beyond the political boundaries of the city. 	<ul style="list-style-type: none"> • Develop regulations and institutional mechanisms to support interregional and cross-sectoral coordination. • Through knowledge coproduction, develop equitable guidelines, standards, and protocols to inform managed retreat. • Revise funding and investment criteria to recognize and value nature-based solutions for cobeneficial adaptation.
Civil society		
<ul style="list-style-type: none"> • Mobilize local leaders in decision-making arenas to advocate for citywide adaptation and resilience thinking. • Enable grassroots awareness and knowledge of climate science, current/future risks, and associated vulnerabilities. • Contest existing paradigms of climate action to offer more people-centered visions of urban development. • Design community-based guidelines for assessing adaptation benefits and losses. 	<ul style="list-style-type: none"> • Develop metrics and criteria for delineating informal, autonomous, or community-based adaptation actions in relation to existing risk-management, vulnerability-reduction, and livelihood-protection schemes. • Bring forth issues of representation of marginalized communities in multiple stakeholder engagement platforms and other decision-making forums. • Articulate locally relevant indicators for ensuring climate equity and justice, taking into the account the need to distribute both adaptation benefits and losses in a fair manner. • Advocate for a review of urban and social policies and programs to identify those that contribute to the criminalization of poverty. 	<ul style="list-style-type: none"> • Harness community-based knowledge and actions to guide decisions around use of nature-based solutions. • Promote social movements, grassroots and community-based networks that address unjust adaptation schemes and advocate for equitable approaches to nature-based solutions. • Ensure that the rights of the most marginalized groups are protected in existing and proposed schemes, including measures to restore floodplains, remove dams and levees, and retreat from zones subject to sea level rise. • Advocate participatory arenas that emphasize interests of marginalized communities.

ROLES OF KEY ACTORS

TABLE 9

High-Priority Adaptation Actions and Roles of Specific Actors in Implementation

				KEY ACTION AREAS		
				1. Spatial planning, infrastructure design and delivery informed by climate risks (continued)	2. Prioritize risk reduction for vulnerable groups and those living in informal settlements (continued)	3. Nature-based solutions for managing water-related and heat risks and for ecosystem protection (continued)
				Private actors		
ROLES OF KEY ACTORS	<ul style="list-style-type: none"> Devise and apply criteria on socioeconomic benefit and financial robustness of adaptation actions. Support objective monitoring and evaluation arrangements for ensuring social accountability and financial transparency. 		<ul style="list-style-type: none"> Provide funds and expertise for cocreation of knowledge. 		<ul style="list-style-type: none"> Support adaptation planning and implementation through engaging with industry and commercial/trade bodies. Synchronize economic logic to adaptation benefits and losses with social, institutional, and ecological criteria. Develop new models and analyze partnership opportunities with government and financial institutions to enable up-front investments in nature-based solutions that can deliver water and heat risk management benefits. 	
					International community	
	<ul style="list-style-type: none"> Support knowledge and tools development for integrating adaptation priorities with urban functions. Support autonomous, flexible, and transparent spending on actions that yield the greatest public good. Support sharing of lessons from best practices in designing integrated, cobeneficial adaptation actions. 		<ul style="list-style-type: none"> Articulate equity and justice criteria within multilateral arrangements that take into account social, political, and economic structures of cities. Support financial, capacity, and technical transfer schemes that take into account local needs, including urban development priorities, urban-rural stressors, as well as informality and poverty-reduction targets. 		<ul style="list-style-type: none"> Revise funding and investment criteria to recognize and value nature-based solutions for cobeneficial adaptation and to ensure that approaches are equitable. Create incentives for cross-department budgeting and program development to advance multiple adaptation benefits. Support learning, skills, and capacity development among urban actors. Foster innovative partnerships around technology exchange and the sharing of good practices. 	

Source: Authors' synthesis.

ENDNOTES

1. We use “cities” to denote areas officially defined as cities and urban areas comprising multiple city jurisdictions.
2. IRP (International Resource Panel). 2018. “The Weight of Cities: Resource Requirements of Future Urbanization,” in *A Report by the International Resource Panel*. Nairobi, Kenya: United Nations Environment Programme (UNEP).
3. S. Hallegatte, C. Green, R.J. Nicholls, and J. Corfee-Morlot. 2013. “Future Flood Losses in Major Coastal Cities.” *Nature Climate Change* 3(9).
4. Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being*. Vol. 5. Washington, DC: Island Press.
5. United Nations, Department of Economic and Social Affairs. 2018. “2018 Revision of World Urbanization Prospects.” New York: United Nations.
6. V. Beard, A. Mahendra, and M. Westphal. 2016. “Towards a More Equal City: Framing the Challenges and Opportunities.” Working Paper. Washington, DC: World Resources Institute.
7. SDI (Slum/Shack Dwellers International). 2018. “Know Your City Initiative.” Nairobi, Kenya: SDI.
8. K.C. Seto, R. Sánchez-Rodríguez, and M. Fragkias. 2010. “The New Geography of Contemporary Urbanization and the Environment.” *Annual Review of Environment and Resources* 35(1): 167–194.
9. IPCC (Intergovernmental Panel on Climate Change). 2018. “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.” Geneva: IPCC.
10. UNRISD (United Nations Research Institute for Social Development). 2016. “Policy Innovations for Transformative Change: Implementing the 2030 Agenda for Sustainable Development.” Geneva: UNRISD. Dunja Krause. 2018. “Transformative Approaches to Address Climate Change and Achieve Climate Justice.” In *Routledge Handbook of Climate Justice*, edited by Tahseen Jafry. London: Routledge.
11. A. Bazaz, P. Bertoldi, M. Buckeridge, A. Cartwright, H. de Coninck, F. Engelbrecht, et al. 2018. “Summary for Urban Policymakers—What the IPCC Special Report on 1.5°C Means for Cities.” Bangalore, India.
12. R. Dhiman, V. Renjith, T. Radhan, I. Eldho, and A. Inamdar. 2019. “Flood Risk and Adaptation in Indian Coastal Cities: Recent Scenarios.” *Applied Water Science* 9(1): 5.
13. C. Rosenzweig, W.D. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, and S.A. Ibrahim. 2018. “Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network.” Cambridge, UK: Cambridge University Press.
14. For more information, see <http://scct-surat.in/>.
15. F. Berkes and H. Ross. 2013. “Community Resilience: Toward an Integrated Approach.” *Society & Natural Resources* 26(1). D. Rodima-Taylor, M.F. Olwig, and N. Chhetri. 2012. “Adaptation as Innovation, Innovation as Adaptation: An Institutional Approach to Climate Change.” *Applied Geography* 33.
16. D. Satterthwaite, D. Archer, S. Colebrand, D. Dodman, and J. Hardoy. 2018. “Responding to Climate Change in Cities and in Their Informal Settlements and Economies.” Background paper for the IPCC Cities and Climate Change Science Conference, Edmonton, Canada. March 5–8.
17. ACHR (Asian Coalition for Housing Rights). 2015. *215 Cities in Asia: Fifth Yearly Report of the Asian Coalition for Community Action*. Bangkok, Thailand: ACHR.
18. SDI. 2018. “Know Your City Initiative.” Nairobi, Kenya: SDI.
19. S. Ozment, R. Feltran-Barbieri, P. Hamel, E. Gray, J.B. Ribeiro, S.R. Barrêto, A. Padovezi, and T.P. Valente. 2018. “Natural Infrastructure in São Paulo’s Water System.” Washington, DC: World Resources Institute.
20. K.A. Gould and T.L. Lewis. 2017. *Green Gentrification: Urban Sustainability and the Struggle for Environmental Justice*. London and New York: Routledge. I. Anguelovski, J.J.T. Connolly, M. Garcia-Lamarca, H. Cole, and H. Pearsall. 2018. “New Scholarly Pathways on Green Gentrification.” *Progress in Human Geography*.
21. Sutherland, C., M. Hordijk, B. Lewis, C. Meyer, and S. Buthelezi. 2014. “Water and Sanitation Provision in Ethekewini Municipality: A Spatially Differentiated Approach.” *Environment and Urbanization* 26(2): 469–488.
22. Beard et al. 2016. “Towards a More Equal City: Framing the Challenges and Opportunities.”
23. R.W. Kates, W.R. Travis, and T.J. Wilbanks. 2012. “Transformational Adaptation When Incremental Adaptations to Climate Change Are Insufficient.” *Proceedings of the National Academy of Sciences* 109(19). J. Mustelin and J. Handmer. 2013. “Triggering Transformation: Managing Resilience or Invoking Real Change.” in *Proceedings of Transformation in a Changing Climate*. Oslo, Norway: University of Oslo.
24. IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, and New York: Cambridge University Press.

25. IRP (International Resource Panel). 2018. "The Weight of Cities: Resource Requirements of Future Urbanization."
26. IRP. 2018. "The Weight of Cities: Resource Requirements of Future Urbanization."
27. Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities."
28. United Nations, Department of Economic and Social Affairs. 2014. "World Urbanization Prospects: The 2014 Revision, Highlights." New York: United Nations, 1.
29. Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities."
30. Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities."
31. J.E. Hardoy, D. Mitlin, and D. Satterthwaite. 2001. *Environmental Problems in Cities of Africa, Asia and Latin America*. London: Earthscan.
32. G. McGranahan, D. Balk, and B. Anderson. 2007. "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones." *Environment and Urbanization* 19(1).
33. Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities."
34. UNRISD (United Nations Research Institute for Social Development). 2016. "Policy Innovations for Transformative Change: Implementing the 2030 Agenda for Sustainable Development." D. Krause. 2018. "Transformative Approaches to Address Climate Change and Achieve Climate Justice."
35. Bazaz et al. 2018. "Summary for Urban Policymakers—What the IPCC Special Report on 1.5°C Means for Cities."
36. IPCC. 2018. "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."
37. Bazaz et al. 2018. "Summary for Urban Policymakers—What the IPCC Special Report on 1.5°C Means for Cities."
38. E. Chu, I. Anguelovski, and J. Carmin. 2016. "Inclusive Approaches to Urban Climate Adaptation Planning and Implementation in the Global South." *Climate Policy* 16(3).
39. I. Anguelovski and J. Carmin. 2011. "Something Borrowed, Everything New: Innovation and Institutionalization in Urban Climate Governance." *Current Opinion in Environmental Sustainability* 3(3).
40. J. Carmin, D. Dodman, and E. Chu. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action." Paris: Organisation for Economic Co-operation and Development (OECD).
- S. Hughes, E.K. Chu, and S.G. Mason. 2018. "Introduction," edited by Sara Hughes, Eric K. Chu, and Susan G. Mason. Cham, Switzerland: Springer.
- A. Hunt and P. Watkiss. 2011. "Climate Change Impacts and Adaptation in Cities: A Review of the Literature." *Climatic Change* 104(1).
41. S. Bartlett and D. Satterthwaite, eds., 2016. *Cities on a Finite Planet: Towards Transformative Responses to Climate Change*. New York: Routledge.
- Chu et al. 2016. "Inclusive Approaches to Urban Climate Adaptation Planning and Implementation in the Global South."
42. E. Chu and K. Michael. 2018. "Recognition in Urban Climate Justice: Marginality and Exclusion of Migrants in Indian Cities." *Environment and Urbanization* 31(1).
- L. Shi, E. Chu, I. Anguelovski, A. Aylett, J. Debats, K. Goh, et al. 2016. "Roadmap towards Justice in Urban Climate Adaptation Research." *Nature Climate Change* 6(2).
43. L. Shi, E. Chu, and J. Debats. 2015. "Explaining Progress in Climate Adaptation Planning across 156 U.S. Municipalities." *Journal of the American Planning Association* 81(3).
- S. Klinsky, H. Dowlatabadi, and T. McDaniels. 2012. "Comparing Public Rationales for Justice Trade-Offs in Mitigation and Adaptation Climate Policy Dilemmas." *Global Environmental Change* 22(4).
- G. Ziervogel, M. Pelling, A. Cartwright, E. Chu, T. Deshpande, L. Harris, et al. 2017. "Inserting Rights and Justice into Urban Resilience: A Focus on Everyday Risk." *Environment and Urbanization* 29(1).
44. Chu et al. 2018. "Recognition in Urban Climate Justice: Marginality and Exclusion of Migrants in Indian Cities." Ziervogel et al. 2017. "Inserting Rights and Justice into Urban Resilience: A Focus on Everyday Risk." E. Chu and K. Michael. 2018. "The Shifting Geographies of Climate Justice: Mobile Vulnerabilities in and across Indian Cities." In *Routledge Handbook of Climate Justice*, edited by Tahseen Jafray. London: Routledge.
45. N. Fraser. 1997. *Justice Interruptus: Critical Reflections on the "Postsocialist" Condition*. New York and London: Routledge.
- N. Fraser. 2000. "Rethinking Recognition." *New Left Review* 3.
- D. Schlosberg. 2009. *Defining Environmental Justice: Theories, Movements, and Nature*. Oxford, UK: Oxford University Press.
46. IPCC. 2018. "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."

47. M.C. Lemos, E. Boyd, E.L. Tompkins, H. Osbahr, and D. Liverman. 2007. "Developing Adaptation and Adapting Development." *Ecology And Society* 12(2).
J. Barnett and S. O'Neill. 2010. "Maladaptation." *Global Environmental Change* 20(2).
48. J. Corfee-Morlot, I. Cochran, S. Hallegatte, and P.-J. Teasdale. 2010. "Multilevel Risk Governance and Urban Adaptation Policy." *Climatic Change* 104(1).
H. Amundsen, F. Berglund, and H. Westskog. 2010. "Overcoming Barriers to Climate Change Adaptation—A Question of Multilevel Governance?" *Environment and Planning C: Government and Policy* 28(2).
J. Ayers. 2009. "International Funding to Support Urban Adaptation to Climate Change." *Environment and Urbanization* 21(1).
H. Bulkeley. 2009. "Planning and Governance of Climate Change." In *Planning for Climate Change: Strategies for Mitigation and Adaptation for Spatial Planners*, edited by Simin Davoudi, Jenny Crawford, and Abid Mehmood. London: Earthscan.
H. Bulkeley. 2010. "Cities and the Governing of Climate Change." *Annual Review of Environment and Resources* 35(1).
D. Roberts. 2010. "Prioritizing Climate Change Adaptation and Local Level Resilience in Durban, South Africa." *Environment and Urbanization* 22(2).
49. A. Jerneck and L. Olsson. 2008. "Adaptation and the Poor: Development, Resilience and Transition." *Climate Policy* 8(2).
S.E.H. Eriksen and K.L. O'Brien. 2007. "Vulnerability, Poverty and the Need for Sustainable Adaptation Measures." *Climate Policy* 7(4).
50. Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities.
51. Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
52. B.M.W. Ratter, K.H.I. Philipp, and H. von Storch. 2012. "Between Hype and Decline: Recent Trends in Public Perception of Climate Change." *Environmental Science & Policy* 18.
P.D. Howe, M. Mildenerger, J.R. Marlon, and A. Leiserowitz. 2015. "Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA." *Nature Climate Change* 5(6).
53. B. Nerlich, N. Koteyko, and B. Brown. 2010. "Theory and Language of Climate Change Communication." *Wiley Interdisciplinary Reviews: Climate Change* 1(1).
54. J. Newig. 2011. "Climate Change as an Element of Sustainability Communication." In *Sustainability Communication: Interdisciplinary Perspectives and Theoretical Foundation*, edited by J. Godemann and G. Michelsen. Dordrecht, the Netherlands: Springer.
R. Gifford, C. Kormos, and A. McIntyre. 2011. "Behavioral Dimensions of Climate Change: Drivers, Responses, Barriers, and Interventions." *Wiley Interdisciplinary Reviews: Climate Change* 2(6).
S. Roeser. 2012. "Risk Communication, Public Engagement, and Climate Change: A Role for Emotions." *Risk Analysis* 32(6).
55. A. Leiserowitz. 2006. "Climate Change Risk Perception and Policy Preferences: The Role of Affect, Imagery, and Values." *Climatic Change* 77(1–2).
E.U. Weber and P.C. Stern. 2011. "Public Understanding of Climate Change in the United States." *American Psychologist* 66(4).
56. N. Pidgeon. 2012. "Public Understanding of, and Attitudes to, Climate Change: UK and International Perspectives and Policy." *Climate Policy* 12(sup01).
N. Pidgeon and B. Fischhoff. 2011. "The Role of Social and Decision Sciences in Communicating Uncertain Climate Risks." *Nature Climate Change* 1(1).
57. J. Carmin, I. Anguelovski, and D. Roberts. 2012. "Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain." *Journal of Planning Education and Research* 32(1).
58. Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
D. Simon. 2012. "Reconciling Development with the Challenges of Climate Change: Business as Usual or a New Paradigm?" In *The Political Economy of Environment and Development in a Globalised World*, edited by Darley Jose Kjosavik, and Paul Vedeld. Oslo, Norway: Tapir Akademisk Forlag.
C.A. Chuku. 2009. "Pursuing an Integrated Development and Climate Policy Framework in Africa: Options for Mainstreaming." *Mitigation and Adaptation Strategies for Global Change* 15(1).
59. D. Archer and D. Dodman. 2017. "The Urbanization of Humanitarian Crises." *Environment and Urbanization* 29(2).
60. D. Archer, F. Almanshi, M. DiGregorio, D. Roberts, D. Sharma, and D. Syam. 2014. "Moving towards Inclusive Urban Adaptation: Approaches to Integrating Community-based Adaptation to Climate Change at City and National Scale." *Climate and Development* 6(4).
61. L. Albrechts. 2004. "Strategic (Spatial) Planning Reexamined." *Environment and Planning B: Planning and Design* 31(5).
62. G. Macleod and M. Goodwin. 1999. "Space, Scale and State Strategy: Rethinking Urban and Regional Governance." *Progress in Human Geography* 23(4).
N. Brenner. 1999. "Beyond State-Centrism? Space, Territoriality, and Geographical Scale in Globalization Studies." *Theory and Society* 28(1).
63. W.N. Adger, J. Barnett, K. Brown, N. Marshall, and K. O'Brien. 2013. "Cultural Dimensions of Climate Change Impacts and Adaptation." *Nature Climate Change* 3(2).
64. Corfee-Morlot et al. 2010. "Multilevel Risk Governance and Urban Adaptation Policy." L.A. Bollinger, C.W.J. Bogmans, E.J.L. Chappin, G.P.J. Dijkema, J.N. Huibregtse, N. Maas, et al. 2013. "Climate Adaptation of Interconnected Infrastructures: A Framework for Supporting Governance." *Regional Environmental Change* 14(3).
65. V. Micale, B. Tonkonogy, and F. Mazza. 2018. "Understanding and Increasing Finance for Climate Adaptation in Developing Countries." *Climate Policy Initiative*.

66. S. Barnard. 2015. "Climate Finance for Cities: How Can International Climate Funds Best Support Low-Carbon and Climate Resilient Urban Development?" in *Working Paper 419*. London: Overseas Development Institute.
67. Micale et al. 2018. "Understanding and Increasing Finance for Climate Adaptation in Developing Countries."
68. T. Schenk. 2017. *Adapting Infrastructure to Climate Change: Advancing Decision-Making under Conditions of Uncertainty*. London and New York: Routledge.
69. E. Chu and T. Schenk. 2017. Communicating about Climate Change with Urban Populations and *Decision-Makers*. *Oxford Research Encyclopedia on Climate Science*, Vol. 1. Oxford, UK, and New York: Oxford University Press.
- L. Shi. 2019. "Promise and Paradox of Metropolitan Regional Climate Adaptation." *Environmental Science & Policy* 92.
70. IPCC. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge, UK, and New York: Cambridge University Press.
- IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.
- IPCC. 2018. "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."
- Beard et al. 2016. "Towards a More Equal City: Framing the Challenges and Opportunities."
- For more information, see: <https://www.unisdr.org/we/coordinate/sendai-framework>; <http://habitat3.org/the-new-urban-agenda/>.
71. Shi, et al. "Explaining Progress in Climate Adaptation Planning across 156 U.S. Municipalities."
- Shi et al. "Roadmap towards Justice in Urban Climate Adaptation Research."
- Chu et al. 2016. "Inclusive Approaches to Urban Climate Adaptation Planning and Implementation in the Global South."
- S. Meerow and C.L. Mitchell. 2017. "Weathering the Storm: The Politics of Urban Climate Change Adaptation Planning." *Environment and Planning: Economy and Space* 49(11): 2619–2627.
- S. Hughes. 2013. "Justice in Urban Climate Change Adaptation: Criteria and Application to Delhi." *Ecology and Society* 18(4).
72. A. Revi, D. Satterthwaite, F. Aragon-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, et al. 2014. "Towards Transformative Adaptation in Cities: The IPCC's Fifth Assessment." *Environment and Urbanization* 26(1).
73. IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.
74. McGranahan et al. 2007. "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones."
75. S. Hallegatte, C. Green, R.J. Nicholls, and J. Corfee-Morlot. 2013. "Future Flood Losses in Major Coastal Cities." *Nature Climate Change* 3(9).
- J. Hinkel, D. Lincke, A.T. Vafeidis, M. Perrette, R.J. Nicholls, R.S.J. Tol, et al. 2014. "Coastal Flood Damage and Adaptation Costs under 21st Century Sea-Level Rise." *Proceedings of the National Academy of Sciences* 111(9).
76. McGranahan et al. 2007. "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones."
77. K.C. Seto, R. Sánchez-Rodríguez, and M. Fragkias. 2010. "The New Geography of Contemporary Urbanization and the Environment." *Annual Review of Environment and Resources* 35(1).
78. C. Rosenzweig, W.D. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, and S.A. Ibrahim. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
79. Research conducted by Deborah Balk (CUNY Institute for Demographic Research, City University of New York), Gordon McGranahan (The Institute for Development Studies), Kytt MacManus (Center for International Earth Science Information Network (CIESIN), Columbia University, and Hasim Engin (CUNY Institute for Demographic Research, City University of New York) for the Coalition for Urban Transitions and the Global Commission on Adaptation, 2019.
80. Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being* 5.
81. U.N. Safriel. 2007. "The Assessment of Global Trends in Land Degradation." in *Climate and Land Degradation*. Berlin and Heidelberg, Germany: Springer.
82. S. Kovats and R. Akhtar. 2008. "Climate, Climate Change and Human Health in Asian Cities." *Environment and Urbanization* 20(1).
83. Seto et al. 2010. "The New Geography of Contemporary Urbanization and the Environment."
84. A. Mahendra and K.C. Seto. 2019. "Upward and Outward Growth: Managing Urban Expansion for More Equitable Cities in the Global South." In *World Resources Report: Towards a More Equal City*. Washington, DC: World Resources Institute (WRI).
85. I. Anguelovski, L. Shi, E. Chu, D. Gallagher, K. Goh, Z. Lamb, K. Reeve, et al. 2016. "Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South." *Journal of Planning Education and Research* 36(3).
86. K. Michael, T. Deshpande, and G. Ziervogel. 2017. "Examining Vulnerability in a Dynamic Urban Setting: The Case of Bangalore's Interstate Migrant Waste Pickers." *SSRN Electronic Journal*.

87. D. Dodman, D. Archer, and D. Satterthwaite. 2019. "Editorial: Responding to Climate Change in Contexts of Urban Poverty and Informality." *Environment and Urbanization* 31(1).
D.S. Williams, M. Máñez Costa, C. Sutherland, L. Celliers, and J. Scheffran. 2019. "Vulnerability of Informal Settlements in the Context of Rapid Urbanization and Climate Change." *Environment and Urbanization* 31(1): 157–176.
88. D. Dodman, J. Bicknell, and D. Satterthwaite, eds. 2012. *Adapting Cities to Climate Change: Understanding and Addressing the Development Challenges*. New York: Routledge.
89. Anguelovski et al. 2016. "Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South."
90. IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.
91. IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.
92. World Bank. 2018. "Financing a Resilient Urban Future: A Policy Brief on World Bank and Global Experience on Financing Climate-Resilient Urban Infrastructure." Washington, DC: The World Bank Group.
93. K.C. Seto, B. Guneralp, and L.R. Hutyrá. 2012. "Global Forecasts of Urban Expansion to 2030 and Direct Impacts on Biodiversity and Carbon Pools." *Proceedings of the National Academy of Sciences* 109(40).
94. C. Rosenzweig, W. Solecki, P. Romero-Lankao, S. Megrotta, S. Dhakal, and S. Ali Ibrahim. 2018. "Commissioned Paper 6 Urban Climate Change Science, Impacts and Vulnerabilities: State-of-the-Art Findings and Key Research Gaps." IPCC Cities.
95. Hallegatte et al. 2013. "Future Flood Losses in Major Coastal Cities."
96. Rosenzweig et al. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
97. Rosenzweig et al. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
98. Rosenzweig et al. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
99. B. World. 2010. *Development and Climate Change: Stepping Up Support to Developing Countries*. Washington, DC: The World Bank.
100. J. Kellett and A. Caravani. 2015. "Financing Disaster Risk Reduction: A 20 Year Story of International Aid." London: Overseas Development Institute.
101. J. Rodin. 2014. *The Resilience Dividend: Being Strong in a World Where Things Go Wrong*. Public Affairs.
102. Rosenzweig et al. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
103. A. Bhattacharya, J.P. Meltzer, J. Oppenheim, Z. Qureshi, and N. Stern. 2016. "Delivering on Sustainable Infrastructure for Better Development and Better Climate." London and Washington, DC: Brookings Institution, New Climate Economy and the Grantham Institute for Climate Change and the Environment.
104. Bhattacharya et al. 2016. "Delivering on Sustainable Infrastructure for Better Development and Better Climate."
105. G. Hughs, P. Chinowsky, and K. Strzepek. 2010. "Development and Climate Change: The Costs of Adapting to Climate Change for Infrastructure." In *Discussion Paper No. 2*. Washington, DC: The World Bank.
- CCFLA (Cities Climate Finance Leadership Alliance). 2015. "State of City Climate Finance 2015." New York: CCFLA.
106. WHO (World Health Organization). 2012. "Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage." Geneva: WHO.
107. Anguelovski et al. 2016. "Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South."
108. S. Colenbrander, M. Lindfield, J. Lufkin, and N. Quijano. 2018. "Financing Low-Carbon, Climate-Resilient Cities." London and Washington, DC: Coalition for Urban Transitions: C40 Climate Leadership Group and WRI Ross Center for Sustainable Cities.
109. L. Bizikova, J. Robinson, and S. Cohen. 2007. "Linking Climate Change and Sustainable Development at the Local Level." *Climate Policy* 7(4).
S.E.H. Eriksen and K. Brown. 2011. "Sustainable Adaptation to Climate Change." *Climate and Development* 3(1).
Eriksen et al. 2007. "Vulnerability, Poverty and the Need for Sustainable Adaptation Measures."
K. Halsnæs, P.R. Shukla, and A. Garg. 2008. "Sustainable Development and Climate Change: Lessons from Country Studies." *Climate Policy* 8(2).
110. J. Ayers and D. Dodman. 2010. "Climate Change Adaptation and Development I." *Progress in Development Studies* 10(2).

111. L. Beckman and E. Page. 2008. "Perspectives on Justice, Democracy and Global Climate Change." *Environmental Politics* 17(4).
- G. Duus-Otterström and S.C. Jagers. 2012. "Identifying Burdens of Coping with Climate Change: A Typology of the Duties of Climate Justice." *Global Environmental Change* 22(3).
- J.T. Roberts. 2009. "The International Dimension of Climate Justice and the Need for International Adaptation Funding." *Environmental Justice* 2(4).
- D. Schlosberg. 2012. "Climate Justice and Capabilities: A Framework for Adaptation Policy." *Ethics & International Affairs* 26(4).
- P.M. Shepard and C. Corbin-Mark. 2009. "Climate Justice." *Environmental Justice* 2(4).
112. A. Escobar. 1995. *Encountering Development: The Making and Unmaking of the Third World*. Princeton, NJ: Princeton University Press.
- J. Friedmann. 1992. *Empowerment: The Politics of Alternative Development*. Cambridge, UK: Blackwell.
- P.A. O'Hara. 2009. "Political Economy of Climate Change, Ecological Destruction and Uneven Development." *Ecological Economics* 69(2).
113. N. Brooks, N. Grist, and K. Brown. 2009. "Development Futures in the Context of Climate Change: Challenging the Present and Learning from the Past." *Development Policy Review* 27(6).
- T. Cannon and D. Müller-Mahn. 2010. "Vulnerability, Resilience and Development Discourses in Context of Climate Change." *Natural Hazards* 55(3).
114. Halsnæs et al. 2008. "Sustainable Development and Climate Change: Lessons from Country Studies."
- J. Pouliotte, B. Smit, and L. Westerhoff. 2009. "Adaptation and Development: Livelihoods and Climate Change in Subarnabad, Bangladesh." *Climate and Development* 1(1).
115. H.-M. Füssel, S. Hallegatte, and M. Reder. 2012. "International Adaptation Funding." In *Climate Change, Justice and Sustainability*, edited by Ottmar Edenhofer, et al. Dordrecht, the Netherlands: Springer.
- J.P. Hoffmaister and M. Román. 2012. "Pursuing the Link between Development and Climate Change Adaptation: The Case of Rice Production in Mozambique." *Climate and Development* 4(3).
- S. Huq and H. Reid. 2004. "Mainstreaming Adaptation in Development." *IDS Bulletin* 35(3).
116. P.G. Bain, T.L. Milfont, Y. Kashima, M. Bilewicz, G. Doron, R.B. Garðarsdóttir, et al. 2016. "Co-Benefits of Addressing Climate Change Can Motivate Action around the World." *Nature Climate Change* 6.
- I. Anguelovski, E. Chu, and J. Carmin. 2014. "Variations in Approaches to Urban Climate Adaptation: Experiences and Experimentation from the Global South." *Global Environmental Change* 27.
117. T.A. Myers, M.C. Nisbet, E.W. Maibach, and A.A. Leiserowitz. 2012. "A Public Health Frame Arouses Hopeful Emotions about Climate Change." *Climatic Change* 113(3-4).
- J. Woodcock, P. Edwards, C. Tonne, B.G. Armstrong, O. Ashiru, D. Banister, et al. 2009. "Public Health Benefits of Strategies to Reduce Greenhouse-Gas Emissions: Urban Land Transport." *The Lancet* 374(9705).
- W.D. Solecki, R. Leichenko, and K. O'Brien. 2011. "Climate Change Adaptation Strategies and Disaster Risk Reduction in Cities: Connections, Contentions, and Synergies." *Current Opinion in Environmental Sustainability* 3(3).
118. J. Birkmann, M. Garschagen, F. Kraas, and N. Quang. 2010. "Adaptive Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change." *Sustainability Science* 5(2).
119. C. Rosenzweig and W. Solecki. 2014. "Hurricane Sandy and Adaptation Pathways in New York: Lessons from a First-Responder City." *Global Environmental Change* 28.
120. J.A. Puppim de Oliveira. 2013. "Learning How to Align Climate, Environmental and Development Objectives in Cities: Lessons from the Implementation of Climate Co-Benefits Initiatives in Urban Asia." *Journal of Cleaner Production* 58.
- J.P. Mayrhofer and J. Gupta. 2016. "The Science and Politics of Co-Benefits in Climate Policy." *Environmental Science & Policy* 57.
121. M. Kok, B. Metz, J. Verhagen, and S. Van Rooijen. 2008. "Integrating Development and Climate Policies: National and International Benefits." *Climate Policy* 8(2).
122. B. Larkin. 2013. "The Politics and Poetics of Infrastructure." *Annual Review of Anthropology* 42(1).
123. T.A. Wall, W.E. Walker, V.A.W.J. Marchau, and L. Bertolini. 2015. "Dynamic Adaptive Approach to Transportation-Infrastructure Planning for Climate Change: San-Francisco-Bay-Area Case Study." *Journal of Infrastructure Systems* 21(4).
124. Anguelovski et al. 2011. "Something Borrowed, Everything New: Innovation and Institutionalization in Urban Climate Governance."
125. R. Bellinson and E. Chu. 2019. "Learning Pathways and the Governance of Innovations in Urban Climate Change Resilience and Adaptation." *Journal of Environmental Policy & Planning* 21(1).
126. Bellinson et al. 2019. "Learning Pathways and the Governance of Innovations in Urban Climate Change Resilience and Adaptation."
127. Bellinson et al. 2019. "Learning Pathways and the Governance of Innovations in Urban Climate Change Resilience and Adaptation."
128. R. Fuchs, M. Conran, and E. Louis. 2011. "Climate Change and Asia's Coastal Urban Cities: Can They Meet the Challenge?" *Environment and Urbanization ASIA* 2(1).

129. J. Birkmann, M. Garschagen, and N. Setiadi. 2014. "New Challenges for Adaptive Urban Governance in Highly Dynamic Environments: Revisiting Planning Systems and Tools for Adaptive and Strategic Planning." *Urban Climate* 7(March).
130. A.K. Jha, R. Bloch, and J. Lamond. 2012. *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*. Washington, DC: The World Bank.
131. C. Ingraham. 2017. "Houston Is Experiencing Its Third 500 Year Flood in 3 Years. How Is That Possible?" Washington Post. https://www.washingtonpost.com/news/wonk/wp/2017/08/29/houston-is-experiencing-its-third-500-year-flood-in-3-years-how-is-that-possible/?utm_term=.65ae7f3e0349.
132. W.H. Butler, R.E. Deyle, and C. Mutnansky. 2016. "Low-Regrets Incrementalism: Land Use Planning Adaptation to Accelerating Sea Level Rise in Florida's Coastal Communities." *Journal of Planning Education and Research* 36(3).
- J. León and A. March. 2016. "An Urban Form Response to Disaster Vulnerability: Improving Tsunami Evacuation in Iquique, Chile." *Environment and Planning B: Planning and Design* 43(5).
- W. Lyles, P. Berke, and K.H. Overstreet. 2018. "Where to Begin Municipal Climate Adaptation Planning? Evaluating Two Local Choices." *Journal of Environmental Planning and Management* 61(11).
133. J. Hardoy and R. Ruete. 2013. "Incorporating Climate Change Adaptation into Planning for a Liveable City in Rosario, Argentina." *Environment and Urbanization* 25(2).
134. A.D. Sari and N. Prayoga. 2018. "Enhancing Citizen Engagement in the Face of Climate Change Risks: A Case Study of the Flood Early Warning System and Health Information System in Semarang City, Indonesia." In *Climate Change in Cities*, edited by Sara Hughes, Eric K. Chu, and Susan G. Mason. Cham, Switzerland: Springer.
- Semarang City Government. 2016. *Resilient Semarang: Moving Together towards a Resilient Semarang*. Semarang, Indonesia: Semarang City Government.
- R. Sutarto and J. Jarvie. 2012. "Integrating Climate Resilience Strategy into City Planning in Semarang, Indonesia." Climate Resilience Working Paper No. 2. Hanoi, Vietnam: Institute for Social and Environmental Transition-International (ISET).
135. S.N.A. Codjoe, F.H. Nyamedor, J. Sward, and D.B. Dovie. 2017. "Environmental Hazard and Migration Intentions in a Coastal Area in Ghana: A Case of Sea Flooding." *Population and Environment* 39(2).
- J.S. Kuma and D.N. Ashley. 2008. "Runoff Estimates into the Weija Reservoir and Its Implications for Water Supply to Accra, Ghana." *Journal of Urban and Environmental Engineering*.
136. R.Q. Huang and Z.M. Xu. 2007. "Environmental Geological Issues of Typical Cities in Southwest China and City Planning." *Geology in China* 34(5).
- X. Wu, X.B. Wang, A.K. Kan, P.H. Peng, and W.D. Chen. 2011. "Watershed Ecological Assessment System of Decision-Making Based on AHP Method." *Journal of Chengdu University of Technology (Science and Technology Edition)* 38(2).
137. J. Ensor and R. Berger. 2009. "Community-based Adaptation and Culture in Theory and Practice." In *Adapting to Climate Change*, edited by W. Neil Adger, Irene Lorenzoni, and Karen O'Brien. Cambridge, UK, and New York: Cambridge University Press.
- T. Forsyth. 2013. "Community-based Adaptation: A Review of Past and Future Challenges." *Wiley Interdisciplinary Reviews: Climate Change* 4.
- D. Rodima-Taylor, et al. 2012. "Adaptation as Innovation, Innovation as Adaptation: An Institutional Approach to Climate Change."
138. F. Berkes and H. Ross. 2013. "Community Resilience: Toward an Integrated Approach." *Society & Natural Resources* 26(1).
- W.N. Adger. 2009. "Social Capital, Collective Action, and Adaptation to Climate Change." *Economic Geography* 79(4).
- M. Pelling and C. High. 2005. "Understanding Adaptation: What Can Social Capital Offer Assessments of Adaptive Capacity?" *Global Environmental Change* 15(4).
- J.P. Brosius, A.L. Tsing, and C. Zerner. 1998. "Representing Communities: Histories and Politics of Community-based Natural Resource Management." *Society & Natural Resources* 11(2).
- S.R. Kellert, J.N. Mehta, S.A. Ebbin, and L.L. Lichtenfeld. 2000. "Community Natural Resource Management: Promise, Rhetoric, and Reality." *Society & Natural Resources* 13(8).
- T. Magee. 2013. *A Field Guide to Community Based Adaptation*. London and New York: Routledge.
- J. Ayers and T. Forsyth. 2009. "Community-based Adaptation to Climate Change." *Environment: Science and Policy for Sustainable Development* 51(4).
- H. Reid and S. Huq. 2014. "Mainstreaming Community-based Adaptation into National and Local Planning." *Climate and Development* 6(4).
139. S. Barrett. 2013. "Local Level Climate Justice? Adaptation Finance and Vulnerability Reduction." *Global Environmental Change* 23(6).
- H. Bulkeley, G.A.S. Edwards, and S. Fuller. 2014. "Contesting Climate Justice in the City: Examining Politics and Practice in Urban Climate Change Experiments." *Global Environmental Change* 25.
- B.C. Parks and J.T. Roberts. 2010. "Climate Change, Social Theory and Justice." *Theory, Culture & Society* 27(2–3).
140. I.M. Young. 1990. *Justice and the Politics of Difference*. Princeton, NJ: Princeton University Press.
- J. Rawls. 1971. *A Theory of Justice*. Cambridge, MA: Harvard University Press.
141. Carmin et al. 2012. "Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain." Anguelovski et al. 2014. "Variations in Approaches to Urban Climate Adaptation: Experiences and Experimentation from the Global South."
142. S. Kernaghan and J. da Silva. 2014. "Initiating and Sustaining Action: Experiences Building Resilience to Climate Change in Asian Cities." *Urban Climate* 7(November).
- D. Sharma, R. Singh, and R. Singh. 2014. "Building Urban Climate Resilience: Learning from the ACCCRN Experience in India." *International Journal of Urban Sustainable Development* 6(2).

143. C. Rosenzweig and W. Solecki. 2010. "Chapter 1: New York City Adaptation in Context." *Annals of the New York Academy of Sciences* 1196.
- J.E. Coffee, J. Parzen, M. Wagstaff, and R.S. Lewis. 2010. "Preparing for a Changing Climate: The Chicago Climate Action Plan's Adaptation Strategy." *Journal of Great Lakes Research* 36.
- J.A. Ekstrom and S.C. Moser. 2014. "Identifying and Overcoming Barriers in Urban Climate Adaptation: Case Study Findings from the San Francisco Bay Area, California, USA." *Urban Climate* 9.
144. Gorakhpur Environmental Action Group. 2013. "Gorakhpur City Resilience Strategy." Gorakhpur, India: ACCCRN.
145. Kernaghan and da Silva. 2014. "Initiating and Sustaining Action: Experiences Building Resilience to Climate Change in Asian Cities." A.V. Bahadur and T. Tanner. 2014. "Policy Climates and Climate Policies: Analysing the Politics of Building Urban Climate Change Resilience." *Urban Climate* 7(March): 20–32.
- A. Brown, A. Dayal, and C. Rumbaitis Del Rio. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." *Environment and Urbanization* 24(2).
146. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." Bahadur and Tanner. 2014. "Policy Climates and Climate Policies: Analysing the Politics of Building Urban Climate Change Resilience." Kernaghan and da Silva. 2014. "Initiating and Sustaining Action: Experiences Building Resilience to Climate Change in Asian Cities."
147. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." Bahadur and Tanner. 2014. "Policy Climates and Climate Policies: Analysing the Politics of Building Urban Climate Change Resilience." Kernaghan and da Silva. 2014. "Initiating and Sustaining Action: Experiences Building Resilience to Climate Change in Asian Cities."
148. Archer et al. 2014. "Moving towards Inclusive Urban Adaptation: Approaches to Integrating Community-based Adaptation to Climate Change at City and National Scale."
149. City of Baltimore. 2019. "2019 Baltimore Sustainability Plan." Baltimore, MD: City of Baltimore.
- City of Seattle. 2005. "Complete Seattle Comprehensive Plan." Seattle, WA: City of Seattle.
- City of Durban. 2017. "Durban Resilience Strategy." eThekweni Municipality, Durban, South Africa.
- Batavia Regional Organisation of Councils. 2010. "Climate Change Adaptation Action Plan." Batavia, Australia: Batavia Regional Organisation of Councils.
- Carmin et al. 2012. "Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain."
- Anguelovski, et al. 2014. "Variations in Approaches to Urban Climate Adaptation: Experiences and Experimentation from the Global South."
- J. Hardoy, E. Gencer, and M. Winograd. 2019. "Participatory Planning for Climate Resilient and Inclusive Urban Development in Dosquebradas, Santa Ana and Santa Tomé." *Environment and Urbanization* 31(1).
- V. Castán Broto, E. Boyd, and J. Ensor. 2015. "Participatory Urban Planning for Climate Change Adaptation in Coastal Cities: Lessons from a Pilot Experience in Maputo, Mozambique." *Current Opinion in Environmental Sustainability* 13.
- UN-Habitat. 2018. "Pro-Poor Climate Action in Informal Settlements." Nairobi: UN-HABITAT.
150. N. Watts, W.N. Adger, S. Ayeb-Karlsson, Y. Bai, P. Byass, D. Campbell-Lendrum, et al. 2017. "The Lancet Countdown: Tracking Progress on Health and Climate Change." *The Lancet* 389(10074).
151. N. Obradovich, R. Migliorini, M.P. Paulus, and I. Rahwan. 2018. "Empirical Evidence of Mental Health Risks Posed by Climate Change." *Proceedings of the National Academy of Sciences* 115(43).
152. H. Orru, K.L. Ebi, and B. Forsberg. 2017. "The Interplay of Climate Change and Air Pollution on Health." *Current Environmental Health Reports* 4(4).
153. T. Gao, X.C. Wang, R. Chen, H.H. Ngo, and W. Guo. 2015. "Disability Adjusted Life Year (DALY): A Useful Tool for Quantitative Assessment of Environmental Pollution." *Science of the Total Environment* 511.
- S. Anand and K. Hanson. 1998. "DALYs: Efficiency Versus Equity." *World Development* 26(2): 307–310.
- A.D. Lopez and C.D. Mathers. 2006. "Measuring the Global Burden of Disease and Epidemiological Transitions: 2002–2030." *Annals of Tropical Medicine & Parasitology* 100(5-6): 481–499.
154. T. Deshpande, K. Michael, and K. Bhaskara. 2019. "Barriers and Enablers of Local Adaptive Measures: A Case Study of Bengaluru's Informal Settlement Dwellers." *Local Environment* 24(3).
- H.B. Lilleør and K. Van den Broeck. 2011. "Economic Drivers of Migration and Climate Change in LDCs." *Global Environmental Change* 21(21).
- S. Parnell and R. Walawege. 2011. "Sub-Saharan African Urbanisation and Global Environmental Change." *Global Environmental Change* 21.
- L. Pasquini. 2019. "The Urban Governance of Climate Change Adaptation in Least-Developed African Countries and in Small Cities: The Engagement of Local Decision-Makers in Dar Es Salaam, Tanzania, and Karonga, Malawi." *Climate and Development* 1–12.
- C. Singh. 2019. "Migration as a Driver of Changing Household Structures: Implications for Local Livelihoods and Adaptation." *Migration and Development* 8(3).
- C. Tacoli. 2009. "Crisis or Adaptation? Migration and Climate Change in a Context of High Mobility." *Environment and Urbanization* 21(2).
155. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."
156. A. Brown. 2018. "Visionaries, Translators, and Navigators: Facilitating Institutions as Critical Enablers of Urban Climate Change Resilience." In *Climate Change in Cities: Innovations in Multi-Level Governance*, edited by Sara Hughes, Eric K. Chu, and Susan G. Mason. Cham, Switzerland: Springer International Publishing.
- E.K. Chu. 2018. "Urban Climate Adaptation and the Reshaping of State-Society Relations: The Politics of Community Knowledge and Mobilisation in Indore, India." *Urban Studies* 55(8).
157. A. Brown. 2018. "Visionaries, Translators, and Navigators: Facilitating Institutions as Critical Enablers of Urban Climate Change Resilience."
158. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."

159. D.P. Aldrich and M.A. Meyer. 2015. "Social Capital and Community Resilience." *American Behavioral Scientist* 59(2).
160. Chu. 2018. "Urban Climate Adaptation and the Reshaping of State-Society Relations: The Politics of Community Knowledge and Mobilisation in Indore, India."
161. S. Barthel and C. Isendahl. 2013. "Urban Gardens, Agriculture, and Water Management: Sources of Resilience for Long-term Food Security in Cities." *Ecological Economics* 86.
- K. Benis and P. Ferrão. 2017. "Potential Mitigation of the Environmental Impacts of Food Systems through Urban and Peri-Urban Agriculture (UPA)—A Life Cycle Assessment Approach." *Journal of Cleaner Production* 140.
162. P. Akhtar, Y.K. Tse, Z. Khan, and R. Rao-Nicholson. 2016. "Data-Driven and Adaptive Leadership Contributing to Sustainability: Global Agri-Food Supply Chains Connected with Emerging Markets." *International Journal of Production Economics* 181.
- D. Lee-Smith. 2010. "Cities Feeding People: An Update on Urban Agriculture in Equatorial Africa." *Environment and Urbanization*.
- Revi et al. 2014. "Towards Transformative Adaptation in Cities: The IPCC's Fifth Assessment."
163. Revi et al. 2014. "Towards Transformative Adaptation in Cities: The IPCC's Fifth Assessment."
- S. Lwasa, F. Mugagga, B. Wahab, and D. Simon, J.P. Connors, and C. Griffith. 2015. "A Meta-Analysis of Urban and Peri-Urban Agriculture and Forestry in Mediating Climate Change." *Current Opinion in Environmental Sustainability* 13.
164. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."
165. F.R. Scarano. 2017. "Ecosystem-based Adaptation to Climate Change: Concept, Scalability and a Role for Conservation Science." *Perspectives in Ecology and Conservation* 15(2).
- A. Triyanti and E. Chu. 2018. "A Survey of Governance Approaches to Ecosystem-based Disaster Risk Reduction: Current Gaps and Future Directions." *International Journal of Disaster Risk Reduction* 32.
166. IUCN. 2019. "Nature-based Solutions." IUCN. <https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions>.
167. R. Munang et al. 2013. "Climate Change and Ecosystem-based Adaptation: A New Pragmatic Approach to Buffering Climate Change Impacts." *Current Opinion in Environmental Sustainability* 5(1).
168. D. Roberts et al. 2012. "Exploring Ecosystem-based Adaptation in Durban, South Africa: 'Learning-by-Doing' at the Local Government Coal Face." *Environment and Urbanization* 24(1).
169. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."
170. M. DiGregorio. 2015. "Bargaining with Disaster: Flooding, Climate Change, and Urban Growth Ambitions in Quy Nhon, Vietnam." *Pacific Affairs* 88(3).
171. T.H. Tuan and B.D. Tinh. 2013. "Cost-Benefit Analysis of Mangrove Restoration in Thi Nai Lagoon, Quy Nhon City, Vietnam." In *IIED ACCCRN Working Paper Series 4*. London: Institute for Environment and Development (IIED).
172. Roberts et al. 2012. "Exploring Ecosystem-based Adaptation in Durban, South Africa: 'Learning-by-Doing' at the Local Government Coal Face."
- Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."
- DiGregorio. 2015. "Bargaining with Disaster: Flooding, Climate Change, and Urban Growth Ambitions in Quy Nhon, Vietnam." *Pacific Affairs*, 88(3), 577–597. <https://doi.org/10.5509/2015883577>.
- T.H. Tuan and B.D. Tinh. 2013. "Cost-Benefit Analysis of Mangrove Restoration in Thi Nai Lagoon, Quy Nhon City, Vietnam."
173. OECD (Organisation for Economic Co-operation and Development). 2018. "Climate Resilient Infrastructure." In *OECD Environmental Policy Paper 14*. Paris: OECD.
174. OECD. 2018. "Climate Resilient Infrastructure."
175. W.J. Mitsch et al. 2012. "Creating Wetlands: Primary Succession, Water Quality Changes, and Self-Design over 15 Years." *BioScience* 62(3).
- L. Lipper et al. 2014. "Climate-Smart Agriculture for Food Security." *Nature Climate Change* 4(12).
176. N. Kabisch, N. Frantzeskaki, S. Pauleit, S. Naumann, M. Davis, M. Artmann, et al. 2016. "Nature-based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action." *Ecology and Society* 21(2).
177. H. Li, L. Ding, M. Ren, C. Li, and H. Wang. 2017. "Sponge City Construction in China: A Survey of the Challenges and Opportunities." *Water* 9(9).
178. I. Anguelovski. 2013. "Beyond a Livable and Green Neighborhood: Asserting Control, Sovereignty and Transgression in the Casc Antic of Barcelona." *International Journal of Urban and Regional Research* 37(3).
- N. Frantzeskaki, S. Borgström, L. Gorissen, M. Egermann, and F. Ehnert. 2017. "Nature-based Solutions Accelerating Urban Sustainability Transitions in Cities: Lessons from Dresden, Genk and Stockholm Cities." In *Nature-based Solutions to Climate Change Adaptation in Urban Areas*, edited by Nadja Kabisch, et al. Cham, Switzerland: Springer.
- C40 Cities. 2019. "Inclusive Climate Action Planning in Practice." London: C40 Cities Leadership Group.

- Li et al. 2017. "Sponge City Construction in China: A Survey of the Challenges and Opportunities." UN-Habitat. 2018. "Pro-Poor Climate Action in Informal Settlements."
179. Gould and Lewis. 2017. *Green Gentrification: Urban Sustainability and the Struggle for Environmental Justice*.
Anguelovski et al. 2018. "New Scholarly Pathways on Green Gentrification."
180. J. da Silva, S. Kernaghan, and A. Luque. 2012. "A Systems Approach to Meeting the Challenges of Urban Climate Change." *International Journal of Urban Sustainable Development* 4(2).
181. Mahendra and Seto. 2019. "Upward and Outward Growth: Managing Urban Expansion for More Equitable Cities in the Global South."
182. For more information, see: <https://cities4forests.com/>.
183. A.A. Mather, G.G. Garland, and D.D. Stretch. 2009. "Southern African Sea Levels: Corrections, Influences and Trends." *African Journal of Marine Science* 31(2).
Golder Associates. 2011. "Community-based Adaptation to Climate Change in Durban." Durban, South Africa.
C. Sutherland, M. Hordijk, B. Lewis, C. Meyer, and S. Buthelezi. 2014. "Water and Sanitation Provision in Ethekewini Municipality: A Spatially Differentiated Approach." *Environment and Urbanization* 26(2).
N. Diederichs and D. Roberts. 2015. *Summary Review of the Durban 2010 FIFA World Cup Event Greening Programme*. Durban, South Africa: Ethekewini Municipality Environmental Planning and Climate Protection Department.
184. Mather et al. 2009. "Southern African Sea Levels: Corrections, Influences and Trends."
Golder Associates. 2011. "Community-based Adaptation to Climate Change in Durban."
Sutherland et al. 2014. "Water and Sanitation Provision in Ethekewini Municipality: A Spatially Differentiated Approach."
Diederichs et al. 2015. *Summary Review of the Durban 2010 FIFA World Cup Event Greening Programme*.
185. T.J. Finan and D.R. Nelson. 2009. "Decentralized Planning and Climate Adaptation: Toward Transparent Governance." In *Adapting to Climate Change Thresholds, Values, Governance*, edited by W. Neil Adger, Irene Lorenzoni, and Karen O'Brien. Cambridge, UK: Cambridge University Press.
Corfee-Morlot et al. 2010. "Multilevel Risk Governance and Urban Adaptation Policy."
Bulkeley. 2009. "Planning and Governance of Climate Change."
186. Finan et al. 2009. "Decentralized Planning and Climate Adaptation: Toward Transparent Governance."
187. B. Smit and J. Wandel. 2006. "Adaptation, Adaptive Capacity and Vulnerability." *Global Environmental Change* 16(3).
J. Mercer. 2010. "Disaster Risk Reduction or Climate Change Adaptation: Are We Reinventing the Wheel?" *Journal of International Development* 22(2).
S. Agrawala and M.K. van Aalst. 2008. "Adapting Development Cooperation to Adapt to Climate Change." *Climate Policy* 8(2).
188. S. Meijerink and S. Stiller. 2013. "What Kind of Leadership Do We Need for Climate Adaptation? A Framework for Analyzing Leadership Objectives, Functions, and Tasks in Climate Change Adaptation." *Environment and Planning C: Government and Policy* 31(2).
189. Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
190. Anguelovski et al. 2014. "Variations in Approaches to Urban Climate Adaptation: Experiences and Experimentation from the Global South."
191. Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
192. Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
193. E. Chu. 2016. "The Political Economy of Urban Climate Adaptation and Development Planning in Surat, India." *Environment and Planning C: Government and Policy* 34(2).
194. E. Ostrom. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK, and New York: Cambridge University Press.
D.C. North. 1990. *Institutions, Institutional Change and Economic Performance*. Cambridge, UK: Cambridge University Press.
195. E. Bryan, T.T. Deressa, G.A. Gbetibouo, and C. Ringler. 2009. "Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints." *Environmental Science & Policy* 12(4).
Chuku. 2009. "Pursuing an Integrated Development and Climate Policy Framework in Africa: Options for Mainstreaming."
S. Aakre and D.T.G. Rübhelke. 2010. "Objectives of Public Economic Policy and the Adaptation to Climate Change." *Journal of Environmental Planning and Management* 53(6).
H. Compston. 2010. "The Politics of Climate Policy: Strategic Options for National Governments." *Political Quarterly* 81(1).
S.C. Moser and J.A. Ekstrom. 2011. "Taking Ownership of Climate Change: Participatory Adaptation Planning in Two Local Case Studies from California." *Journal of Environmental Studies and Sciences* 1(1).
196. I.R. Noble, S. Huq, Y.A. Anokhin, J. Carmin, D. Goudou, F.P. Lansigan, et al. 2014. "Adaptation Needs and Options." In *Climate Change 2014 Impacts, Adaptation, and Vulnerability*, edited by Vicente R. Barros Christopher B. Field, David Jon Dokken, Katharine J. Mach, and Michael D. Mastrandrea. Cambridge, UK: Cambridge University Press.
197. C. Moser and D. Satterthwaite. 2010. "Toward Pro-Poor Adaptation to Climate Change in Urban Centres of Low- and Medium-Income Countries." In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, edited by Robin Mearns and Andrew Norton. Washington, DC: The World Bank.

198. Carmin et al. 2012."Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain." Carmin et al. 2013. "Urban Climate Adaptation and Leadership: From Conceptual Understanding to Practical Action."
199. Anguelovski et al. 2011."Something Borrowed, Everything New: Innovation and Institutionalization in Urban Climate Governance." Carmin et al. 2012."Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain." D. Roberts. 2008. "Thinking Globally, Acting Locally—Institutionalizing Climate Change at the Local Government Level in Durban, South Africa." *Environment and Urbanization* 20(2).
200. Anguelovski et al. 2011."Something Borrowed, Everything New: Innovation and Institutionalization in Urban Climate Governance." Carmin et al. 2012."Urban Climate Adaptation in the Global South: Planning in an Emerging Policy Domain."
201. R. Few, K. Brown, and E.L. Tompkins. 2007. "Public Participation and Climate Change Adaptation: Avoiding the Illusion of Inclusion." *Climate Policy* 7(1).
K.L. Ebi and J.C. Semenza. 2008. "Community-based Adaptation to the Health Impacts of Climate Change." *American Journal of Preventive Medicine* 35(5).
Ayers and Forsyth. 2009."Community-based Adaptation to Climate Change."
E. Boyd, N. Grist, S. Juhola, and V. Nelson. 2009. "Exploring Development Futures in a Changing Climate: Frontiers for Development Policy and Practice." *Development Policy Review* 27(July 2008).
202. Anguelovski et al. 2011."Something Borrowed, Everything New: Innovation and Institutionalization in Urban Climate Governance." W.N. Adger, S. Huq, K. Brown, D. Conway, and M. Hulme. 2003. "Adaptation to Climate Change in the Developing World." *Progress in Development Studies* 3(3).
Huq et al. 2004."Mainstreaming Adaptation in Development."
D. Dodman and D. Satterthwaite. 2009. "Institutional Capacity, Climate Change Adaptation and the Urban Poor." *IDS Bulletin* 39(4).
203. L. Chelleri, J.J. Waters, M. Olazabal, and G. Minucci. 2015. "Resilience Trade-Offs: Addressing Multiple Scales and Temporal Aspects of Urban Resilience." *Environment and Urbanization* 27(1).
C.J. Uittenbroek, L.B. Janssen-Jansen, and H.A.C. Runhaar. 2013. "Mainstreaming Climate Adaptation into Urban Planning: Overcoming Barriers, Seizing Opportunities and Evaluating the Results in Two Dutch Case Studies." *Regional Environmental Change* 13(2).
204. F. Kraas. 2007. "Megacities and Global Change: Key Priorities." *The Geographical Journal* 173(79–82). Birkmann et al. 2010. "Adaptive Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change." Birkmann, et al. 2014. "New Challenges for Adaptive Urban Governance in Highly Dynamic Environments: Revisiting Planning Systems and Tools for Adaptive and Strategic Planning." E. Boyd and S. Juhola. 2015. "Adaptive Climate Change Governance for Urban Resilience." *Urban Studies* 52(7).
205. Birkmann et al. 2010."Adaptive Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change."
206. Boyd, and Juhola. 2015. "Adaptive Climate Change Governance for Urban Resilience."
207. K. Krellenberg and B. Hansjürgens, eds. 2014. *Climate Adaptation Santiago*. Berlin and Heidelberg, Germany: Springer.
208. P. Romero-Lankao, S. Hughes, A. Rosas-Huerta, R. Borquez, and D.M. Gnatz. 2013. "Institutional Capacity for Climate Change Responses: An Examination of Construction and Pathways in Mexico City and Santiago." *Environment and Planning C: Government and Policy* 31(5).
209. Krellenberg and Hansjürgens. 2014. *Climate Adaptation Santiago*.
210. K. Krellenberg and B. Katrin. 2014. "Inter- and Transdisciplinary Research for Planning Climate Change Adaptation Responses: The Example of Santiago de Chile." *Interdisciplinary Science Reviews* 39(4).
211. J.R. Barton. 2013. "Climate Change Adaptive Capacity in Santiago de Chile: Creating a Governance Regime for Sustainability Planning." *International Journal of Urban and Regional Research* 37(6).
212. J.R. Barton, K. Krellenberg, and J.M. Harris. 2015. "Collaborative Governance and the Challenges of Participatory Climate Change Adaptation Planning in Santiago de Chile." *Climate and Development* 7(2).
213. IPCC. 2014. "Summary for Policymakers." In *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, edited by Vicente R. Barros Christopher B. Field, David Jon Dokken, Katharine J. Mach, and Michael D. Mastrandrea. Cambridge, UK: Cambridge University Press.
214. Noble et al. 2014. "Adaptation Needs and Options."
215. T. Schenk. 2017. *Adapting Infrastructure to Climate Change: Advancing Decision-Making under Conditions of Uncertainty*. London and New York: Routledge.
S. Tyler and M. Moench. 2012. "A Framework for Urban Climate Resilience." *Climate and Development* 4(4).
216. Noble et al. 2014. "Adaptation Needs and Options."
217. Noble et al. 2014. "Adaptation Needs and Options."
218. Brown et al. 2012."From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience."
219. Brown et al. 2012."From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." Chu. 2016."The Political Economy of Urban Climate Adaptation and Development Planning in Surat, India."
220. Brown et al. 2012."From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." Chu. 2016."The Political Economy of Urban Climate Adaptation and Development Planning in Surat, India."

221. Brown et al. 2012. "From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience." Chu. 2016. "The Political Economy of Urban Climate Adaptation and Development Planning in Surat, India."
222. Shi et al. 2016. "Roadmap towards Justice in Urban Climate Adaptation Research."
223. G. Ziervogel et al. 2017. "Inserting Rights and Justice into Urban Resilience: A Focus on Everyday Risk." *Environment and Urbanization* 29(1).
224. IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*
225. A. Fung. 2006. "Varieties of Participation in Complex Governance." *Public Administration Review* 66(s1).
J.E. Innes and D.E. Booher. 2010. *Planning with Complexity: An Introduction to Collaborative Rationality for Public Policy.* New York: Routledge.
226. K.L. Ebi. 2009. "Facilitating Climate Justice through Community-based Adaptation in the Health Sector." *Environmental Justice* 2(4).
A. Rahman, G. Rabbani, D. Mallick, and N. Haider. 2012. *Community Based Adaptation: Early Learnings from CBA Conferences. Conference Proceedings, Vol. 1.* Dhaka, Bangladesh: Bangladesh Centre for Advanced Studies (BCAS).
227. Forsyth. 2013. "Community-based Adaptation: A Review of Past and Future Challenges."
P. Pringle and D. Conway. 2012. "Voices from the Frontline: The Role of Community-Generated Information in Delivering Climate Adaptation and Development Objectives at Project Level." *Climate and Development* 4(2).
228. SDI. 2018. "Know Your City Initiative."
229. SDI. 2018. "Know Your City Initiative."
230. K. Kern and H. Bulkeley. 2009. "Cities, Europeanization and Multi-Level Governance: Governing Climate Change through Transnational Municipal Networks." *Journal of Common Market Studies* 47(2).
T. Lee. 2013. "Global Cities and Transnational Climate Change Networks." *Global Environmental Politics* 13(1).
231. Finan et al. 2009. "Decentralized Planning and Climate Adaptation: Toward Transparent Governance."
T. Bernauer and R. Gampfer. 2013. "Effects of Civil Society Involvement on Popular Legitimacy of Global Environmental Governance." *Global Environmental Change* 23(2).
232. H.J. Aslin and K.L. Blackstock. 2010 "Now I'm Not an Expert in Anything: Challenges in Undertaking Transdisciplinary Inquiries across the Social and Biophysical Sciences." In *Tackling Wicked Problems through the Transdisciplinary Imagination.* London and Washington, DC: Earthscan, 117–129.
233. Schlosberg. 2012. "Climate Justice and Capabilities: A Framework for Adaptation Policy."
234. G.I. Orderud and M. Winsvold. 2012. "The Role of Learning and Knowledge in Adapting to Climate Change: A Case Study of Norwegian Municipalities." *International Journal of Environmental Studies* 69(6): 946–961.
235. Ziervogel et al. 2017. "Inserting Rights and Justice into Urban Resilience."
236. B. Resurrección, I. Dankelman, M. Haldar, C.P. McMullen, and C.M.Y. Park. 2019. "Gender-Transformative Climate Change Adaptation: Advancing Social Equity." Paper commissioned by the Global Commission on Adaptation (GCA).
237. Hughes. 2013. "Justice in Urban Climate Change Adaptation." H. Bulkeley, J. Carmin, V.C. Broto, G.A. Edwards, and S. Fuller. 2013 "Climate Justice and Global Cities: Mapping the Emerging Discourses." *Global Environmental Change* 23(5): 914–925.
238. Shi et al. 2016. "Roadmap towards Justice in Urban Climate Adaptation Research."
R.J. Brulle, J. Carmichael, and J.C. Jenkins. 2012. "Shifting Public Opinion on Climate Change: An Empirical Assessment of Factors Influencing Concern over Climate Change in the U.S., 2002–2010." *Climatic Change* 114(2).
Howe et al. 2015. "Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA."
239. Brulle et al. 2012. "Shifting Public Opinion on Climate Change: An Empirical Assessment of Factors Influencing Concern over Climate Change in the U.S., 2002–2010."
240. C. Callison. 2014. *How Climate Change Comes to Matter: The Communal Life of Facts.* Durham, NC: Duke University Press.
M. Lahsen. 2007. "Trust through Participation? Problems of Knowledge in Climate Decision Making." In *The Social Construction of Climate Change: Power, Norms, and Discourses*, edited by Mary E. Pettenger. Aldershot, UK: Ashgate.
241. Krellenberg et al. 2014. "Inter- and Transdisciplinary Research for Planning Climate Change Adaptation Responses: The Example of Santiago de Chile."
242. Anguelovski et al. 2016. "Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South."
243. R. Friend, J. Jarvie, S.O. Reed, R. Sutarto, P. Thinphanga, and V.C. Toan. 2014. "Mainstreaming Urban Climate Resilience into Policy and Planning: Reflections from Asia." *Urban Climate* 7.
244. E.K. Chu. 2018. "Transnational Support for Urban Climate Adaptation: Emerging Forms of Agency and Dependency." *Global Environmental Politics* 18(3).

245. D. Marks. 2015. "The Urban Political Ecology of the 2011 Floods in Bangkok: The Creation of Uneven Vulnerabilities." *Pacific Affairs* 88(3).
J. Thaipadungpanit, V. Wuthiekanun, N. Chantratita, S. Yimsamran, P. Amornchai, S. Boonsilp, et al. 2013. "Short Report: Leptospira Species in Floodwater during the 2011 Floods in the Bangkok Metropolitan Region, Thailand." *American Journal of Tropical Medicine and Hygiene* 88(4).
D. Marks and F. Thomalla. 2017. "Responses to the 2011 Floods in Central Thailand: Perpetuating the Vulnerability of Small and Medium Enterprises?" *Natural Hazards* 87(2).
246. Rosenzweig et al. 2018. "Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network."
247. World Bank. 2018. "Financing a Resilient Urban Future: A Policy Brief on World Bank and Global Experience on Financing Climate-Resilient Urban Infrastructure." Washington, DC: The World Bank.
248. M.J. Cook and E.K. Chu. 2018. "Between Policies, Programs, and Projects: How Local Actors Steer Domestic Urban Climate Adaptation Finance in India." In *Climate Change in Cities: Innovations in Multi-Level Governance*, edited by Sara Hughes, Eric Chu, and Susan Mason. Cham, Switzerland: Springer.
249. Agrawala and van Aalst. 2008. "Adapting Development Cooperation to Adapt to Climate Change."
250. R.J.T. Klein. 2010. "Mainstreaming Climate Adaptation into Development: A Policy Dilemma." In *Climate Governance and Development, Berlin Workshop Series*, edited by Ansohn Albrecht and Boris Pleskovic. Washington, DC: The World Bank.
251. Cook and Chu. 2018. "Between Policies, Programs, and Projects: How Local Actors Steer Domestic Urban Climate Adaptation Finance in India."
A. Gouldson, S. Colenbrander, A. Sudmant, F. McAnulla, N. Kerr, P. Sakai, et al. 2015. "Exploring the Economic Case for Climate Action in Cities." *Global Environmental Change* 35.
252. M. Bapna and H. McGray. 2009. "Financing Adaptation: Opportunities for Innovation and Experimentation." In *WRI Conference Papers*, edited by Lael Brainard, Abigail Jones, and Nigel Purvis. Washington, DC: Brookings Institution Press.
253. J. Bruggmann. 2012. "Financing the Resilient City." *Environment and Urbanization* 24(1).
254. J.M. Keenan, E. Chu, and J. Peterson. 2019. "From Funding to Financing: Perspectives Shaping a Research Agenda for Investment in Urban Climate Adaptation." *International Journal of Urban Sustainable Development*.
J.M. Keenan. 2018. "Regional Resilience Trust Funds: An Exploratory Analysis for Leveraging Insurance Surcharges." *Environment Systems and Decisions* 38(1).
255. A. Persson and E. Remling. 2014. "Equity and Efficiency in Adaptation Finance: Initial Experiences of the Adaptation Fund." *Climate Policy* 14(4).
D. Ciptet, J.T. Roberts, and M. Khan. 2013. "The Politics of International Climate Adaptation Funding: Justice and Divisions in the Greenhouse." *Global Environmental Politics* 13(1).
256. S. Colenbrander, D. Dodman, and D. Mitlin. 2017. "Using Climate Finance to Advance Climate Justice: The Politics and Practice of Channelling Resources to the Local Level." *Climate Policy* 18(7).
257. D. Brautigam, O.-H. Fjeldstad, and M. Moore, eds. 2008. *Taxation and State-Building in Developing Countries: Capacity and Consent*. Cambridge, UK: Cambridge University Press.
M. Moore. 2007. "How Does Taxation Affect the Quality of Governance?" *Tax Notes International* 47(1).
M. Moore. 2004. "Revenues, State Formation, and the Quality of Governance in Developing Countries." *International Political Science Review* 25(3).
W. Prichard. 2010. "Taxation, Responsiveness and Accountability in Sub-Saharan Africa." Sussex, UK: University of Sussex.
W. Prichard and D.K. Leonard. 2010. "Does Reliance on Tax Revenue Build State Capacity in Sub-Saharan Africa?" *International Review of Administrative Sciences* 76(4).
258. Chu. 2018. "Transnational Support for Urban Climate Adaptation: Emerging Forms of Agency and Dependency."
A. Atteridge, M.K. Shrivastava, N. Pahuja, and H. Upadhyay. 2012. "Climate Policy in India: What Shapes International, National and State Policy?" *Ambio* 41(Suppl 1).
W.P. Pauw. 2015. "Not a Panacea: Private-Sector Engagement in Adaptation and Adaptation Finance in Developing Countries." *Climate Policy* 15(5).
259. Pauw. 2015. "Not a Panacea: Private-Sector Engagement in Adaptation and Adaptation Finance in Developing Countries."
260. Colenbrander et al. 2018. "Financing Low-Carbon, Climate-Resilient Cities."
261. Satterthwaite et al. 2018. "Responding to Climate Change in Cities and in Their Informal Settlements and Economies."
262. Confederation of Danish Industry. n.d. "Climate Adapted Cities: Solutions from Copenhagen." Copenhagen: Confederation of Danish Industry.
Government of Denmark. 2012. "Action Plan for a Climate-Proof Denmark." Copenhagen: Government of Denmark.
263. Confederation of Danish Industry. n.d. "Climate Adapted Cities: Solutions from Copenhagen."
Government of Denmark. 2012. "Action Plan for a Climate-Proof Denmark."
264. For more information, see: <http://cdia.asia/>.

265. IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC. 2014. "Summary for Policymakers."
266. N.J. Toly. 2008. "Transnational Municipal Networks in Climate Politics: From Global Governance to Global Politics." *Globalizations* 5(3).
H. Fünfgeld. 2015. "Facilitating Local Climate Change Adaptation through Transnational Municipal Networks." *Current Opinion in Environmental Sustainability* 12.
267. Chu. 2018. "Transnational Support for Urban Climate Adaptation: Emerging Forms of Agency and Dependency."
268. Brown. 2018. "Visionaries, Translators, and Navigators: Facilitating Institutions as Critical Enablers of Urban Climate Change Resilience."
269. M. Wolfram, J. van der Heijden, S. Juhola, and J. Patterson. 2018. "Learning in Urban Climate Governance: Concepts, Key Issues and Challenges." *Journal of Environmental Policy & Planning* 21(1).
J.J. Patterson, T. Thaler, M. Hoffmann, S. Hughes, A. Oels, E. Chu, et al. 2018. "Political Feasibility of 1.5°C Societal Transformations: The Role of Social Justice." *Current Opinion in Environmental Sustainability* 31.
270. Adger et al. 2013. "Cultural Dimensions of Climate Change Impacts and Adaptation."
271. IPCC. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*.
272. S. Parnell. 2016. "Defining a Global Urban Development Agenda." *World Development* 78.
273. M.B.A. van Asselt and O. Renn. 2011. "Risk Governance." *Journal of Risk Research* 14(4).
274. Noble et al. 2014. "Adaptation Needs and Options."
275. D. Bours, C. McGinn, and P. Pringle. 2013. "Monitoring & Evaluation for Climate Change Adaptation: A Synthesis of Tools, Frameworks and Approaches." Phnom Penh, Cambodia, and Oxford, UK: SEA Change CoP and UKCIP.
276. Bours et al. 2013. "Monitoring & Evaluation for Climate Change Adaptation: A Synthesis of Tools, Frameworks and Approaches."
277. Noble et al. 2014. "Adaptation Needs and Options."
278. Bours et al. 2013. "Monitoring & Evaluation for Climate Change Adaptation: A Synthesis of Tools, Frameworks and Approaches." ARUP and Rockefeller Foundation. 2018. "City Resilience Index." ARUP. <https://cityresilienceindex.org/#/>.
T. Leiter, A. Olhoff, R. Al Azar, V. Barmby, D. Bours, V.W.C. Clement, et al. 2019. "Adaptation Metrics: Current Landscape and Evolving Practices." Rotterdam, the Netherlands, and Washington, DC.
279. Y.C. Lee, J. Ahern, and C.T. Yeh. 2015. "Ecosystem Services in Peri-Urban Landscapes: The Effects of Agricultural Landscape Change on Ecosystem Services in Taiwan's Western Coastal Plain." *Landscape and Urban Planning* 139.
Mahendra et al. 2019. "Upward and Outward Growth: Managing Urban Expansion for More Equitable Cities in the Global South."

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