10

Urban Health

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Managing Threats to Human Health

Climate change and extreme events are increasing risks of disease and injury in cities. Urban health systems have a significant role to play in preparing for these exacerbated risks. Climate risk information and early warning systems for adverse health outcomes are needed to enable interventions. An increasing number of cities are engaging with health adaptation planning, but health departments of all cities need to be prepared.

Major Findings

- Storms, floods, heat extremes, and landslides are among the most important weather-related health hazards in cities. Climate change will increase the risks of morbidity and mortality in urban areas due to greater frequency of weather extremes. Children, the elderly, the sick, and the poor in urban areas (i.e., those with proportionally low incomes in comparison to the local residents) are particularly vulnerable to extreme climate events.

- Some chronic health conditions (e.g., respiratory and heat-related illnesses) and infectious diseases will be exacerbated by climate change. These conditions and diseases are often prevalent in urban areas.

- The public's health in cities is highly sensitive to the ways in which climate extremes disrupt buildings, transportation, waste management, water supply and drainage systems, electricity, and fuel supplies. Making urban infrastructure more resilient will lead to better health outcomes, both during and following climate events.

- Health impacts in cities can be reduced by adopting "low-regret" adaptation strategies in the health system and throughout other sectors, such as water resources, wastewater and sanitation, environmental protection, and urban planning.

- Actions aimed primarily at reducing greenhouse gas emissions in cities can also bring immediate local health benefits and reduced costs to the health system through a range of pathways, including reduced air pollution, improved access to green space, and opportunities for active transportation on foot or bicycle.

Key Messages

In the near term, improving basic public health and health care services, developing and implementing early warning systems; and training citizens' groups in disaster preparedness, recovery, and resilience are effective adaptation measures.

The public health sector, municipal governments, and the climate change community should work together to integrate health as a key goal in the policies, plans, and programs of all city sectors.

Connections between climate change and health should be made clear to public health practitioners, city planners, policy-makers, and to the general public. Collaborative efforts, focused for example on the identification of vulnerable residents and resources, have been recognized as effective for enhancing community resiliency during extreme events.

10.1 Introduction

Cities are complex, and the actions of different urban sectors influence their populations' health (see Figure 10.1). Climate change is expected to affect the frequency and severity of existing diseases and may also threaten progress toward reducing the burden of climate-related disease and injury (Smith et al., 2014). Urban health systems should be prepared for potentially enhanced disease risks related to climate change (see Box 10.1).

The effectiveness of programs and measures to address any health burden attributable to climate change depends upon a variety of factors, including the current burden of disease, the effectiveness of current interventions, and projections for where, when, and how climate change is expected to affect the health burden. Equally relevant is the feasibility of implementing additional programs in light of different stakeholders' engagement with the problem and the surrounding social, economic, and political setting.

In this context, the use of scientific knowledge can be vital to the protection of urban citizens' health and well-being. For example, health sector specialists can use climate information effectively in epidemic early warning systems to help select which interventions to initiate (Ghebreyesus et al., 2009). The challenge for the scientific community is to generate and communicate this knowledge in a way that can usefully inform policy choices based on the realities of the urban environment. Improved data and knowledge will be critical to reduce citizens' vulnerability to climate hazards, as well as existing inequities and social injustice in cities, and to assess the health co-benefits of strategies to mitigate greenhouse gas (GHG) emissions.

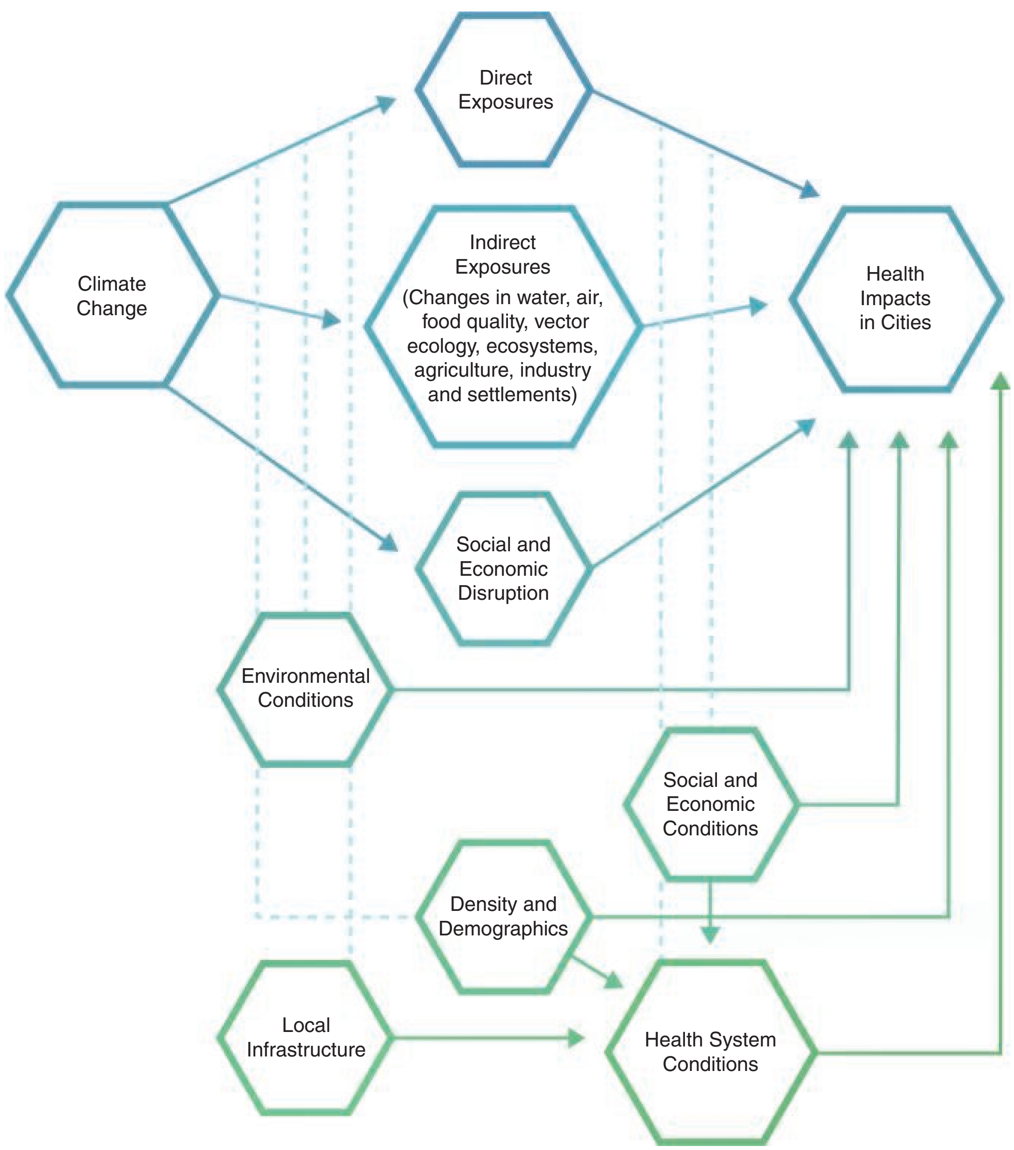

Figure 10.1 *Climate change and health in cities.*

Source: Adapted from IPCC, 2007

Box 10.1 Health and Health Systems in Cities

This chapter uses the definition applied by the World Health Organization (WHO) for *health* and *health systems* where *health* "is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization [WHO], 1946). This definition strengthens the idea of health as the ability to adapt and to self-manage (Rydin et al., 2012). Within this notion of *health*, Rydin includes Amartya Sen's idea of *justice,* entailing the ability to live a life one has reason to value. In cities, *health* is associated with social, economic, and environmental determinants (Barata et al., 2011), including climate change. There is a large and continually expanding body of research presenting that the way in which cities are planned and managed can make a substantial difference to the health of their residents (Rydin et al., 2012). The WHO writes that *health systems* include all the organizations, institutions, and resources that are devoted to produce actions principally aimed at improving, maintaining, or restoring health (WHO, 2005). Therefore, a public health system should advocate for healthy policies, plans, and projects for all urban sectors. Long-term projections of global health outcomes now explicitly include factors such as unsafe water, food, and residence; poor sanitation; urban air pollution; and indoor air pollution – all of which are aggravated by climate change (see Section 10.3). Thus, a health impact assessment of urban polices, plans, and projects is critical when planning and managing cities as well as when implementing city adaptation and mitigation strategies related to climate change hazard.

Figure 10.2 *Examples of ARC3.2 Case Study Docking Station cities that have implemented mitigation and adaptation strategies with co-benefits for their health systems.*

Since publication of the First Urban Climate Change Research Network Assessment Report on Climate Change and Cities (ARC3.1) chapter on climate change and human health, important progress has been made. Reviews of climate and urban climate change adaptation strategies in key cities (Carmin et al., 2012a; Castán Broto and Bulkeley, 2013; Revi et al., 2014) find that an increasing number of cities are engaging with health adaptation planning. These reports also provide a number of research and Case Studies of the potential health co-benefits of mitigation and adaptation activities and include examples drawn from the Global South. Meanwhile, the Fifth Assessment Report (AR5) developed by the Intergovernmental Panel on Climate Change (Intergovernmental Panel Climate Change [IPCC], 2014) provides an updated report of the international scientific

Table 10.1 *Climate change–related drivers and benefits from implemented adaptation and mitigation strategies.*

Drivers	Country	City	Health endpoint	Adaptation and Mitigation Strategies	Benefits
Heavy rainfall	Brazil	Nova Friburgo	Increase in the incidence of leptospirosis and dengue fever	Syndromic approach	Prepare the health sector to react to extreme events
	Canada	Calgary	Mental health illness	Improvement in infrastructure	Reduce city infrastructure and operational vulnerabilities
		Toronto	Loss of well-being and foodborne illnesses	Investment in order to reduce the impact of future flood events	Improve wastewater and storm water collection systems and increase public education efforts
	India	Uttarakhand (13 districts)	Deaths and loss of well-being	Improvement in infrastructure	Optimal utilization of water resources
Heat wave	Canada	Windsor	Deaths	Heat alert and response plan	Create a strong health system that can protect the most vulnerable populations
	Australia	Brisbane	Deaths and years-of-life-lost	Urban green infrastructure	Reduce local ambient temperature
	India	Ahmedabad	Dehydration; acute heat illnesses; cardiovascular diseases; kidney diseases; respiratory diseases	Heat action plan and extreme heat early warning system	Alert the population on heat risks and prevention measures and forecast extreme weather temperatures
	USA	New York	Deaths and respiratory illness	Urban green infrastructure (Million Trees NYC Project)	Reduce atmospheric CO_2; reduce local ambient temperature; improve air quality and reduce storm water runoff
Reduction of CO_2	China	Kunshan	Growing health system demand	Building of three new healthcare facilities using green technology	Energy and water efficiency; disaster-resilient health system with self-contained tertiary health care facilities

community's most current knowledge of the human health impacts of climate change. This includes emerging human health risks in cities and applied responses to prevent and mitigate them (Mustelin et al., 2013).

In this chapter, we summarize the scientific evidence concerning climate-related human health risks in urban areas and discuss responses for reducing these risks in light of climate change. In Section 10.2, the process of stakeholder engagement is discussed. The extent to which the health sector and other relevant stakeholders confront the challenges of climate change and promote the well-being of all citizens is considered. In Section 10.3, an overview of the current knowledge of climate change hazards, health impacts, and urban health vulnerabilities is presented. Section 10.4 turns to adaptation strategies to protect city residents from some of the health impacts and risks posed by climate change. In Section 10.5 we discuss mitigation strategies that, while aimed at reducing GHG emissions, also provide so-called co-benefits to human health. Section 10.6 presents barriers and bridges to mitigation and adaptation strategies. Section 10.7 highlights knowledge gaps and recommended areas for further research, and in Section 10.8 some policy recommendations are presented as a conclusion of the assessment presented in this chapter.

10.2 Public Engagement

Public engagement (Greenwood, 2007) is essential to all stages of climate change assessment, from the initial planning stage through the implementation, monitoring, response, and evaluation phases of successful urban risk management response to climate change (URMRCC). Box 10.2 presents the process, advantages, barriers, and challenges of the implementation of a stakeholder engagement strategy.

Box 10.2 Stakeholder Engagement Process, Steps, Barriers, and Challenges

Stakeholder engagement provides a wealth of benefits to planning and response processes. First, this engagement fosters innovation by harnessing collective potential to identify key issues. Stakeholders can empower those outside the decision-making process and ensure that community concerns are taken into account. They can also help increase credibility, identify vulnerable populations, mobilize resources and networks, aid in fact-checking, and provide different social perspectives for planning. Stakeholders' long-term contributions include improved community relations, lasting capability for action, and conflict mitigation. Finally, fostering stakeholder engagement makes room for the development of alternative solutions, which can reduce response times, mitigate risks, and stimulate learning (IPCC, 2007; Admassie et al., 2008; Littell, 2010).

PROCESS AND STEPS FOR STAKEHOLDER ENGAGEMENT

The literature presents many frameworks for engaging stakeholders. According to Kema Inc. (2012), the process of stakeholder engagement begins with establishing a team, identifying goals and an audience, and determining a timeline and resources. It concludes with developing outreach materials and implementing an engagement strategy. Similarly, a five-step stakeholder engagement process is used by the Canadian government, starting by identifying stakeholders and proceeding toward understanding the reasons for stakeholder engagement, planning the engagement process, commencing the dialogue, and, last, maintaining the dialogue and delivering on commitments (Hohnen, 2007; Schmeer, K. 1999).

Pragmatically speaking, the level at which climate and health activities are likely to be pursued – and the capacity to pursue these activities at that level – are both important factors to consider in adaptation planning. It is important to house adaptation activities within the appropriate level of department or organization to ensure that both willingness and capacity are maximized. Similarly, endorsement by senior management is central, but the ongoing engagement of mid-level stakeholders is also important for the result of the adaptation process.

LESSONS, BARRIERS, AND CHALLENGES TO STAKEHOLDER ENGAGEMENT

Stakeholder engagement can be time-consuming and costly. To go beyond research to action, it is important that stakeholders take ownership of the adaptation process. Additionally, the provision of appropriate staff time and funds is important for successful stakeholder involvement. Finally, the process should not be focused on technical modeling issues and reports written in technical jargon (adapted from CAP, 2007).

Several barriers exist to stakeholder engagement, including time commitments and impractical timescales (e.g., when the time requested to deliver on goals is inadequate). When working in international settings, gender, language, and cultural barriers (e.g., males and females working together) can also pose challenges to successful stakeholder engagement. Trust must be cultivated, especially in community settings where stakeholders from different interest groups (e.g., the private sector, government, nongovernmental organizations [NGOs], citizen's groups, and academia) may be involved. Stakeholders previously engaged in other similar settings may have already worked to meet challenges and may be reluctant to engage due to fears of redundancy, and power struggles between groups and community members challenge stakeholder engagement when visions are not shared (Weible, 2007; Stott and Walton, 2013).

O'Haire et al. (2011) provide a helpful list of factors that can transform these barriers into successful endeavors, beginning with:

- Engaging stakeholders early in the process to gauge their ability to participate (identifying time constraints and the type and amount of information each group or member can provide)
- Ensuring that the engagement is consistent and ongoing (building trust with the stakeholders)
- Preparing and providing material for the stakeholders to ensure an equal level of knowledge (providing additional information if needed can decrease issues later in the engagement process)
- Allowing each stakeholder (individual or group) equal participation in the process to reduce any unnecessary power dynamics that may decrease engagement effectiveness
- Reinforcing understanding of stakeholders' duties so that *scope-creep*, in which duties extend beyond those originally identified, does not occur.

Facilitators should ensure proper time management as much as possible, be neutral and encourage participation from all stakeholders, and be familiar not only with the health issue but with the cultural and community setting that they are working.

Stakeholders provide diverse perspectives and data to the decision-making process. Examples of possible health impacts related to climate change and the potential relevant stakeholders who are able to provide information and support for reducing those impacts to populations in cities, are listed here:

- *Vector-borne and infectious diseases*: Epidemiologists (to identify changes in infection rates), hospitals (to respond to public health emergencies and treat patients), and social workers and local community members and groups (to help identify vulnerable populations and respond to environmental health needs)
- *Heat-related illnesses (including stroke, respiratory and cardiovascular distress)*: Local municipalities' decision-makers (to develop and implement heat-health warning and response policies), the media (to alert the public to extreme heat events and locations of cooling centers), and independent power producers and utilities (who provide electricity for cooling and maintain infrastructure)
- *Water quality and water-borne diseases:* Emergency preparedness organizations (first responders for flood events), municipal planning departments (to upgrade sewer and drainage systems), and water management departments (to detect changes in water quality)
- *Air quality, asthma, allergies*: Meteorology services, air quality managers, public health and/or medical schools, NGOs and research scientists (to conduct research on air quality and health impacts), private sectors (who may contribute to GHG emissions but may also produce valuable products, including medications for respiratory distress)

Engaging stakeholders and improving governance in light of the health risks of climate change in cities requires understanding how the health system is structured. As the WHO writes, a health system involves the organizations, institutions, resources, and people whose main purpose is to improve health. Bowen et al. (2012) present an integrated view of the institutions and sectors relevant to the health risks of climate change (see Figure 10.3).

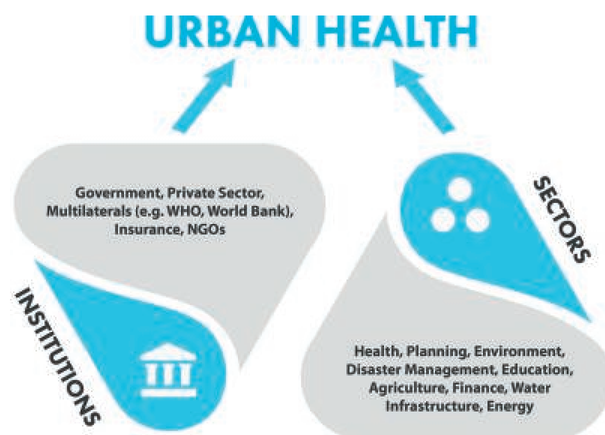

Figure 10.3 *Integrated view of the institutions and sectors relevant to the health risks of climate change.*

Source: Adapted from Bowen et al., 2012

The WHO is responsible for providing global and sectoral leadership. The WHO shapes the global health research agenda, sets norms and standards, articulates evidence-based policy options, provides technical support to countries, and monitors and assesses health trends (information available on their website). WHO headquarters takes the lead in coordinating climate change and health work across United Nations agencies. Regional and country offices work directly with national ministries of health, providing technical support and guidance.

In most countries, at the national level, the ministry of health is the primary contact for efforts to manage the health risks of climate change. The ministry of health often coordinates and collaborates with a national climate change team and serves as a resource for regional and local adaptation efforts. Such cooperative efforts need to be enhanced, particularly in low- and middle-income countries. For example, a policy analysis of Fiji's National Climate Change Policy, National Climate Change Adaptation Strategy, and Public Health Act found that the health risks of climate change were considered only to a minor extent and that supporting documents in sectors such as water and agriculture did not consider health risks (Morrow and Bowen, 2014).

In Fiji, the incidence of dengue, waterborne diseases, and undernutrition will likely be affected by climate change, which means that these risks should be addressed with sectorial and climate change–specific policies. International and academic collaboration may be also useful, as can be seen in Case Study 10.1.

Although some cities are responsible for their own health system's functions, others are embedded within a multilayered hierarchy of responsibilities directed by the ministry of health. Capacity to monitor and respond to climate change health threats at a municipal level is likely to vary alongside capacities in other areas and may be lower than at the national level (Paterson et al., 2012; Bierbaum et al., 2013). Managing the health risks of climate change is complex; it often requires a cross-sectorial collaboration (see Case Study 10.1), and it should be considered when designing a stakeholder engagement strategy.

Case Study 10.1 Participative Development of a Heat-Health Action Plan in Ahmedabad, India

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Keywords	Heat waves, adaptation action plan, early warning system, India
Population (Metropolitan Region)	6,352,254 (Census Bureau of India, 2011)
Area (Metropolitan Region)	1,866 km^2 (Ahmedabad Urban Development Authority, 2016)
Income per capita	US$1,680 (World Bank, 2017)
Climate zone	BSh – Arid, steppe, hot arid (Peel et al., 2007)

The city of Ahmedabad is an important economic and industrial hub in western India, located in the center-north of the State of Gujarat along the banks of Sabarmati River. The city's urban population has increased from 4.5 million (2001) to 6.3 million (2011) in just 10 years (Government of India, 2011; Census Bureau of India, 2011), making it one of the fastest growing urban regions within India and worldwide (Kotkin, 2010).

The climate in Ahmedabad on the Köppen climate scale is hot semi-arid (BSh) with three distinct seasons: winter, summer, and monsoon. Temperatures usually get extremely hot before the monsoon arrives: average monthly high temperatures (1971–2000) are 39.7°C (April), 41.6°C (May), and 38.7°C (June), with record high temperatures climbing as high as 47–48°C.

Heat waves pose a threat for the public health system already today – not only in Ahmedabad, but also in many other Indian cities. Heat waves cause fatalities and are related to dehydration, acute heat illnesses (heat exhaustion or heat stroke), cardiovascular diseases, kidney diseases, and respiratory diseases (Knowlton et al., 2014). In Ahmedabad, this particularly affects poor slum dwellers (25.8% of the city's population in 2006) (Tran et al., 2013) where adaptation options such as adequate drinking water supply or air condition are frequently missing and poor environmental conditions (e.g., water quality, air pollution) and work conditions (especially for outdoor workers) already exacerbate pressures for human health (Knowlton et al., 2014).

Climate change is expected to increase the frequency and intensity of prolonged periods of high temperatures (Smith et al., 2014), with urban heat islands likely exacerbating vulnerability to extreme heat caused by global warming (Smith et al., 2014).

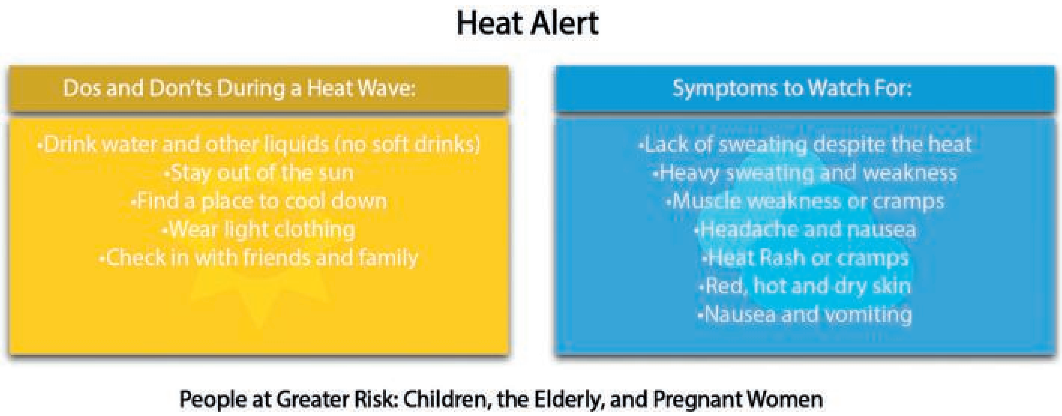
In this context, a team of American and Indian research institutions, the Indian Institute of Public Health, and the Ahmedabad Municipal Corporation joined forces following a severe heat wave in 2010 to start the Ahmedabad Heat and Climate Study Group (see Knowlton et al., 2014). The group's task focused on the design and implementation of two distinct but integrated instruments: a Heat Action Plan (HAP), and an Extreme Heat Early Warning System that informs the HAP (Knowlton et al., 2014; Ahmedabad Municipal Corporation [AMC], 2013, 2015).

The HAP integrates awareness-building (alerting the population on heat risks and prevention measures) through different media, capacity-building programs for health professionals, and a simple warning system. Classification of heat emergencies according to their degree of severity triggers a different set of responsibilities and actions for each institutional actor participating in the HAP. The Extreme Heat Early Warning System comprises a probabilistic weather forecasting system for extreme temperatures and the probability that specific extreme temperature thresholds will in fact be exceeded. Heat waves are projected with a seven-day advance lead time in order to allow Ahmedabad officials time to plan and coordinate public health and interagency responses.

The design and implementation process of both HAP and the Extreme Heat Early Warning System included considerable stakeholder feedback: for example, the project's needs assessment – focused on the characterization of susceptible populations, evaluation of earlier heat wave impacts, assessment of health sector capacity to deal with heat wave conditions, and the like – organized comprehensive focus group meetings and roundtables with experts such as medical professionals, meteorologists, and health agency personnel, but also included community leaders and media experts. Site visits to hospitals and informal settlements to understand community needs and to gain trust also among non-expert participants complemented this broad approach (Knowlton et al., 2014).

This open and participatory approach has been conducted at all steps of HAP and Extreme Heat Early Warning System development, from the initial project design phase to data collection to intervention development and project implementation. In fact, maintaining communications open and coordinated at all stages of the project, including the possibility to discuss working methodologies with experts and non-experts, has strongly contributed to establishing trusted relationships between the project team and partners while in turn also increasing overall acceptance of the outcomes and buy-in from relevant stakeholders (Knowlton et al., 2014).

Both the HAP and Extreme Heat Early Warning System are currently implemented and in use (AMC, 2013, 2015), and evaluation of effectiveness and efficiency of the project is currently ongoing. Future plans for Ahmedabad include the integration of additional



Case Study 10.1 Figure 1 *Alerting the population on heat risks and prevention measures.*

Source: Adapted from Knowlton et al., 2014

components into the project approach (e.g., promoting green infrastructure for cooling microclimate or developing dedicated heat avoidance training programs for children and their mothers), but also studying existing air pollution problems in Ahmedabad as a possibly confounding factor for heat-related mortality and transferring existing measures to other cities across Gujarat State.

Box 10.3 Stakeholder Engagement for an Effective Heat Wave Early Warning and Response System

Establishing an effective heat wave early warning and response system involves, at minimum, representatives of public health, meteorology, hospital, and media groups engaged in planning and outreach activities.

White-Newsome et al. (2014) surveyed the steps for establishing an effective heat wave early warning and response system. They interviewed leaders from government and nongovernmental organizations representing the public health, general social services, emergency management, meteorology, and environmental planning sectors in four U.S. cities chosen for their diverse demographics, climates, and climate adaptation strategies (Detroit, Michigan; New York, New York; Philadelphia, Pennsylvania; and Phoenix, Arizona). The interviews identified activities that could reduce the harmful effects of high ambient temperatures and described the obstacles faced in implementing them. Cooling centers, heat wave early warning systems, programs to distribute fans and/or air conditioning, and outreach programs were common across the cities. The local context (including local political will, availability of resources, and the maturity of local community organizations) was an important consideration both for the success of efforts to identify and reach the most vulnerable populations and for optimizing the use of health statistics. The primary obstacles faced were financial constraints, promoting the effective use of cooling centers, and communication issues; addressing these issues requires a multisectoral approach.

Considering that stakeholder engagement should include citizens' groups, individual citizens need to know how to recognize symptoms of heat exposure and learn basic ways to stay cool as they access other available community-level heat-health resources. Educating citizens to understand how to protect and increase their resilience must be a key component of overall community response to health challenges related to climate change (see Case Study 10.1).

10.3 Climate Hazards, Vulnerabilities, and Opportunities

Urban areas are vulnerable to the health impacts of climate change due to their high population density, concentration of vulnerable populations, higher temperatures compared to surrounding areas, and, in many cases, exposure to coastal storms. Increase in climate-related temperatures, amplified intensity of storms and related flooding, storm surge in coastal and low-lying urban areas, and changes in vector-borne and infectious diseases are all examples of climate-related health impacts that have the potential to affect public health in urban areas. In addition, the health of urban residents is closely linked to key infrastructure, such as public transportation, sewerage, waste management, the efficiency of rainwater drainage systems, and the utility supply. When climate-related extreme events threaten critical urban infrastructure, reverberations can be felt in the health of urban populations (see Figure 10.4).

10.3.1 Storms and Flooding

Urban populations in coastal and low-lying regions are often vulnerable to the impacts of extreme storms and flooding. The number of people living near coasts and within areas likely to be impacted by storm-related flooding events is large (NCA 2014, ch. 2). Health impacts of extreme storms depend on interactions between the storm's particular characteristics and the characteristics of the affected communities and may include direct effects (e.g., death and injury) and indirect, long-term effects (e.g., infrastructure damage, contamination of water and soil, and changes in vector-borne diseases, respiratory health, and mental health) (Lane et al., 2013). Flooding can induce the creation of breeding sites for vectors and can lead to bacterial contamination of water sources, resulting in outbreaks of infectious disease. Storms and flooding can also mobilize chemical toxins from industrial or contaminated sites (Ruckart et al., 2008). Elevated indoor moisture and mold levels associated with flooding of interior spaces have been identified as risk factors for cough, wheeze, and childhood asthma (Jaakkola et al., 2005). Mental health impacts may be among the most common and long-lasting impacts of extreme storms; to date, however, they have received relatively little study (Berry et al., 2010). Evacuation and disruptions in access to communications and health care delivery are all correlates of extreme storms that can adversely affect health. The stress of evacuation, property damage, economic loss, and household disruption, as well as knowledge of trauma and deaths, are among the triggers of adverse mental health impacts that have been identified among storm-affected populations (Weisler et al., 2006).

10.3.2 Temperature Extremes

Heat has a direct impact on all-cause mortality, with peaks in mortality occurring on the same day or shortly after exposure to heat. In urban areas, residential environments may pose significant risk for fatal heat exposure during heat waves; for example, more than 80% of heat stroke deaths in New York have been attributed to exposure at home (Wheeler et al., 2013). Demographic groups including children, the elderly, and people with pre-existing health impairments may be particularly vulnerable to such stresses (Romero-Lankao et al., 2013).

While mortality represents the most severe health outcome of extreme heat, increases in emergency room visits and in hospital admissions for heat-sensitive diseases have also been observed during heat episodes (Knowlton et al., 2009; Lin et al., 2009). A limited amount of evidence suggests that exposure to elevated temperatures may also have an impact on adverse birth outcomes such as preterm birth (Basu et al., 2010).

For both urban mortality and nonfatal temperature-related illnesses (e.g., heat stroke, heat exhaustion, hyperthermia), temperature threshold levels are city-specific and depend on latitude and normal average temperatures (Harlan and Ruddell, 2011). In their study of twelve urban agglomerations in low- and middle-income countries, McMichael et al. (2008) found that thresholds for heat-related morbidity ranged from 16°C to 31°C, with higher threshold levels in cities with warmer climates. Figure 10.5 presents the overall cumulative heat–mortality relationships in four cities in different regions of the world. There

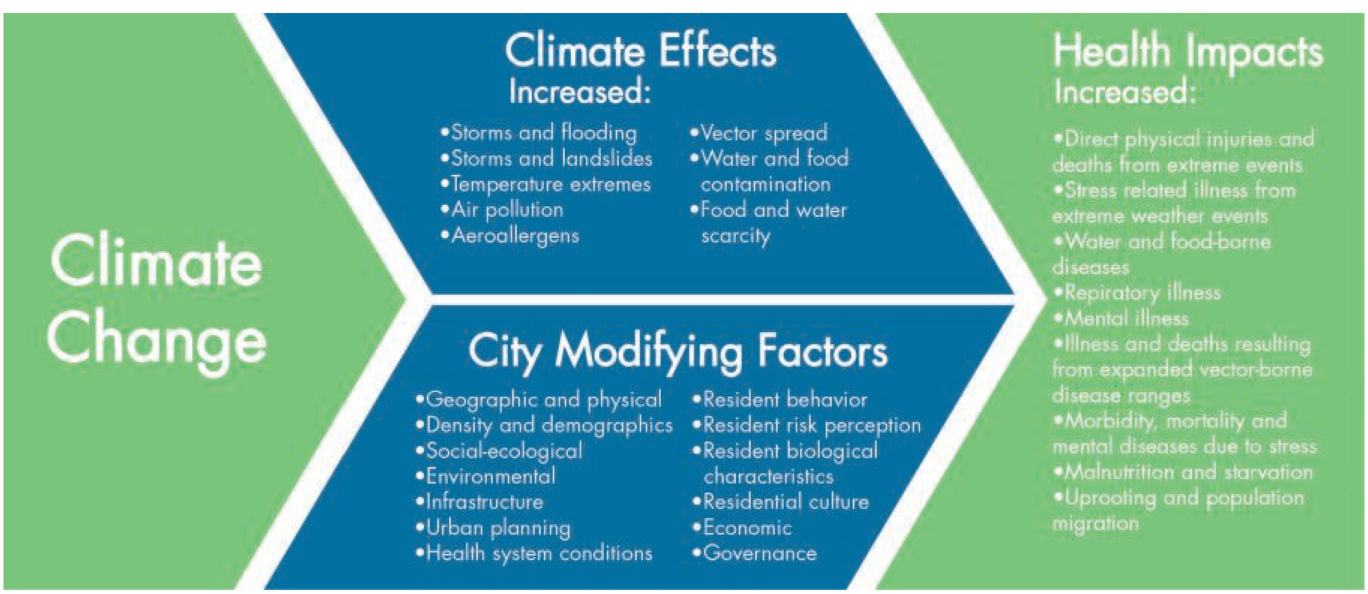


Figure 10.4 *How climate change affects citizens' health.*

Source: Rozenzweig et al., 2011

Case Study 10.2 Health and Social Cost of Disaster: Nova Friburgo, State of Rio de Janeiro, Brazil

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Keywords	Rainfall, extreme event, health, health care costs, syndromic approach
Population (Metropolitan Region)	184,786 (Instituto Brasileiro de Geografia e Estatística [IBGE], 2015)
Area (Metropolitan Region)	933,415 km^2 (Instituto Brasileiro de Geografia e Estatística [IBGE], 2015)
Income per capita	US$8,840 (World Bank, 2017)
Climate zone	Cfb – Warm temperate, fully humid, warm summer (Peel et al., 2007)

In the Mountain Region of the state of Rio de Janeiro in Brazil, urban sprawl, urban population density, and deficits in basic sanitation services increase the severity of the environmental and human impacts of extreme events. Additionally, among the 14 municipalities located in this region, Nova Friburgo, Petrópolis, and Teresópolis have the highest vulnerability due to their geomorphology and high population density. These cities were vulnerable and not well prepared to avoid damages caused by precipitation.

In January 2011, heavy rains fell on the Mountain Region, causing one of the most severe natural disasters ever recorded in Brazil. The United Nations ranked it as the eighth largest landslide to have occurred worldwide in the past 100 years. More than 900 deaths occurred, and nearly 35,000 people were left homeless or displaced in the affected municipalities of the Mountain Region.

Because of the disaster, 3,000 landslides were registered in Nova Friburgo, with resulting damages to water, energy, transport, telecommunications, and health services. In this city, 429 people died and 3,220 were left homeless (Pereira et al., 2014). The disaster also triggered a significant increase in the incidence of leptospirosis and dengue fever in the city (see Case Study 10.2 Figures 1 and 2).

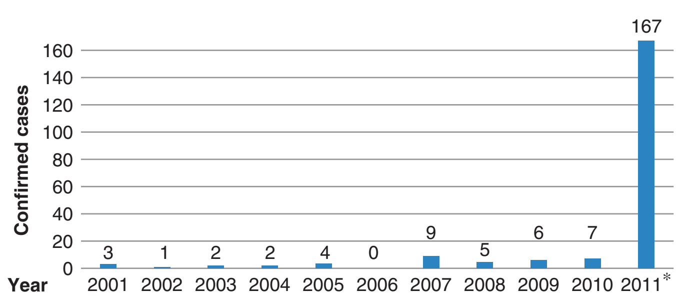
A partial economic assessment was conducted to evaluate the social cost of the leptospirosis and dengue fever cases attributed to this natural disaster in Nova Friburgo. It considered both direct (health care costs) and indirect costs (loss for society, considering loss of school and work days, as well as lost productivity). The study used restricted-access secondary data provided by the Municipal Health Surveillance and Primary Care Health Sector. Income data included the 2011 prevailing national and state minimum wages and the estimated average income of the local population.

The study also evaluated avoided costs achieved via a syndromic surveillance system adopted by the local Service of Epidemiological Surveillance just after the disaster. It consisted of the administration of specific medication for disease treatment even if there was no diagnostic confirmation, a procedure in which the presence of three major characteristic symptoms of the disease was required. This measure aimed to prevent worsening of patients' condition before their diagnoses were confirmed and avoid increased social costs caused by the disease. The necessary information for calculating the avoided cost of treatment was obtained from charts used for syndromic surveillance; namely, the medications administered, duration of treatment, and dates of procedures. The cost of the syndromic approach comprised drug expenses as well as the cost of the health care team performing the procedure. As reported by the Epidemiological Surveillance Service of the municipality, the State of Rio de Janeiro Health Department professionals performed the first procedures and interventions at the calamity site. After this team left, the city staff continued the job.

The total social cost of leptospirosis cases attributed to the 2011 disaster ranged between US$22,000 and US$66,000. The adopted empirical therapy (syndromic approach) represented a total avoided cost of US$14,800, in addition to a reduction in lethality (i.e., thirty-one deaths were avoided among confirmed cases of the disease, and no deaths resulted from the leptospirosis cases attributed to the natural disaster) (Instituto Oswaldo Cruz-Fiocruz, 2013).

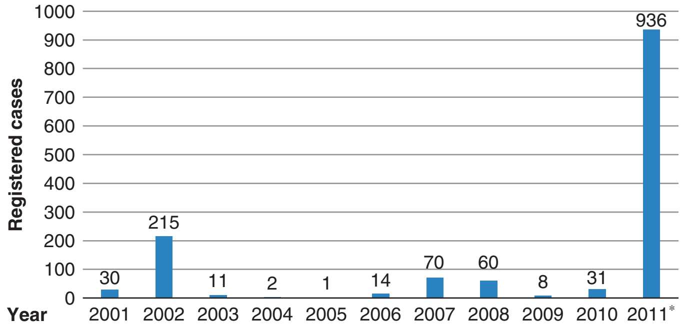
The disaster also triggered a significant increase in the incidence of dengue fever in Nova Friburgo. Moreover, there was an increase in sites for mosquito breeding, which facilitated the proliferation of dengue fever in this city, where its incidence had previously been low. The social cost of the disease was evaluated using the same methodology applied for the cases of leptospirosis raging between US$29,000 and US$219,000 (Instituto Oswaldo Cruz-Fiocruz, 2013).

The increase in these diseases was associated with extensive changes in the city's environment (e.g., sanitation and urban cleaning programs were interrupted in the post-event period).



Case Study 10.2 Figure 1 *Confirmed cases of leptospirosis in Nova Friburgo, Rio de Janeiro State between 2001 and 2011.*

Source: SINAN



Case Study 10.2 Figure 2 *Registered cases of dengue in Nova Friburgo, Rio de Janeiro State between 2001 and 2011.*

Source: SINAN

In fact, there has been a significant post-disaster long-term rise in leptospirosis and dengue fever incidence in the municipality. This study illustrates the potential for increased cases of a vector-borne infectious disease following a natural disaster. A disease outcome such as this brings significant costs to the health sector and to society. Underestimation of these costs and underappreciation of these risks are clearly problems to be confronted in urban planning for climate change adaptation. Estimation of the social cost of natural disaster–related disease outcomes can help encourage the adoption of ongoing preventive measures that can protect urban residents from these types of adverse health outcomes.

Source: Archive of authors, 2012. Produced from the database of the Brazilian Institute of Geography and Statistics (IBGE); Pereira et al. (2014b; 2014c)

is consensus that exposure–response functions for health effects due to heat exposure do not follow a strict linear trend but instead have U-, V-, or J-shapes (McMichael et al., 2008; Romero-Lankao et al., 2013). In addition to heat extremes, cold temperatures can also be associated with ill-health, although the causal pathways remain unclear in many cases (Smith et al. 2014). In a meta-analysis of 224 city studies, Romero-Lankao et al. (2012) found that deaths increase as temperatures fall below or rise above certain threshold values. The thresholds are noteworthy since they may be assumed as measures of heat or cold tolerance,

Case Study 10.3 Windsor Heat Alert and Response Plan: Reaching Vulnerable Populations

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Keywords	Heat, public health, response plan
Population (Metropolitan Region)	210,891 (Government of Canada, 2015)
Area (Metropolitan Region)	146.32 km^2 (Government of Canada, 2015)
Income per capita	US$43,660 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

Cities are built to accommodate high-density populations, favoring impervious concrete surfaces and low-albedo material over natural forests and sprawling ecosystems. These planning designs create, absorb, and retain heat (urban heat island) increasing temperatures by up to 12°C over surrounding rural areas (Oke, 1997). In August 2003, the temperature in France went 12°C above the mean maximum temperature for nine successive days (Fouillet, 2006) resulting in more than 70,000 deaths across Europe (Robine et al., 2008). Following this extreme heat event, many cities moved to proactively develop heat-related policies that would (1) create stronger public health systems and (2) implement adaptation measures to decrease residents' vulnerability to these life-threatening heat events. To further complicate matters, climate change is projected to cause an increase in the frequency and intensity of extreme heat events and having the potential to triple heat-related deaths (IPCC, 2014).

Following the release of Environment Canada's climate projections for Southern Ontario, the City of Windsor and the County of Essex enacted a three-tier Heat Alert and Response Plan (City of Windsor, 2013). The plan goes beyond Public Health Unit involvement to include nongovernmental organizations (NGOs), community groups, decision-makers, first responders, hospitals, pharmacist, and utilities to help identify and reach the most vulnerable populations before and during extreme heat events.

When a heat event occurs,[1] the Windsor-Essex Heat Alert and Response Plan triggers Public Health Units, the Red Cross, the City of Windsor and County Municipalities, NGOs, and neighboring cities to coordinate, prepare, notify, report, and exchange information and resources relating to the heat event. Each group has defined roles that include:

- Monitoring Environment Canada's Humidex forecast, April through October
- Preparing first responders with heat-health messaging
- Assisting with the dissemination of information regarding extreme heat events
- Notifying media and community partners of change in alert level
- Providing a list of public facilities with air conditioning (and generators) with normal hours of operation that the general public can access if required
- Coordinating with Windsor Essex County Health Unit to develop heat-health messaging
- Providing emergency medical response to the public during extreme heat events
- Providing volunteers, including member of the First Aid Service (FAS) team to provide support

1 In Canada, a heat wave is defined as three or more consecutive days in which the maximum temperature is greater than or equal to 32°C.

- Exchanging information with the Windsor Essex County Health Unit prior to and during extreme heat events
- Coordinating with Detroit to develop heat-health messaging
- Reporting to the Medical Officer of Health the prevalence of heat-related illnesses

Case Study 10.3 Table 1 provides a brief illustration of each level of the system.

Prior to the heat event, the plan identifies vulnerable populations and individuals who will be contacted (during the alert) by phone or visited in their communities by volunteer groups and NGOs. A Community Emergency Management Coordinator (CEMC) will contact the local utilities to ensure that disaster plans are in place in case of a power outage. Pharmacists are asked to complete a report at the end of the day that will help identify any changes in access during the heat event. A municipal website (staycoolwindsoressex.com) is maintained and updated regularly before and during the heat alert along with a call center to help residents easily access information including cooling center locations and signs and symptoms relating to heat-related illnesses. These actions are pre-empted by a public awareness campaign that is held prior to the start of each warm season to remind and educate residents of the potential impacts of heat to their health and well-being.

All these measures are vitally important to create a strong public health system that protects the most vulnerable populations with the aim of having them understand the risks associated with extreme heat events and to aid them in finding assistance prior to them being at risk. These proactive measures allow cities to (1) understand who is vulnerable (2) identify where these vulnerable populations live (3) determine the cities hot spots, and (4) develop and enact plans with community partners. A final component of the plan is to research adaptation strategies in order to build a more heat-resilient community that will reduce a changing climate's impact on their community.

Case Study 10.3 Table 1 *City of Windsor and the County of Essex Three-Tier Heat Alert and Response Plan. Source: Adapted from http://www.staycoolchatham-kent.com*

Monitoring	The Windsor-Essex County Health Unit is monitoring the Humidex forecast for extreme heat events. The Humidex is a combination of temperature (°C) and humidity (%) to reflect perceived temperature
Level 1	One or more days reaching Humidex 40
Level 2	Four or more days reaching Humidex 40
	One or more days reaching Humidex 45
	Four or more nights above Humidex 28
Level 3	A heat emergency is issued in response to a severe or prolonged emergency, such as power outages or water shortages

or as the "comfort range" that changes depending on such factors as city location and age and that is expected to be affected by climate change (Romero-Lankao et al., 2012). Vardoulakis et al. (2014) developed a comparative assessment of the effects of climate change on heat- and cold-related mortality in cities of United Kingdom and Australia. According to their analysis, cold-related mortality currently accounts for more deaths than heat-related mortality in cities in the United Kingdom (around 61 and 3 deaths per 100,000 population per year) and from Australia (around 33 and 2 deaths per 100,000 population per year), respectively (Vardoulakis et al., 2014). Others have argued that high death rates in winter are not caused by cold temperatures but rather by other factors that vary across seasons (Kinney et al., 2015).

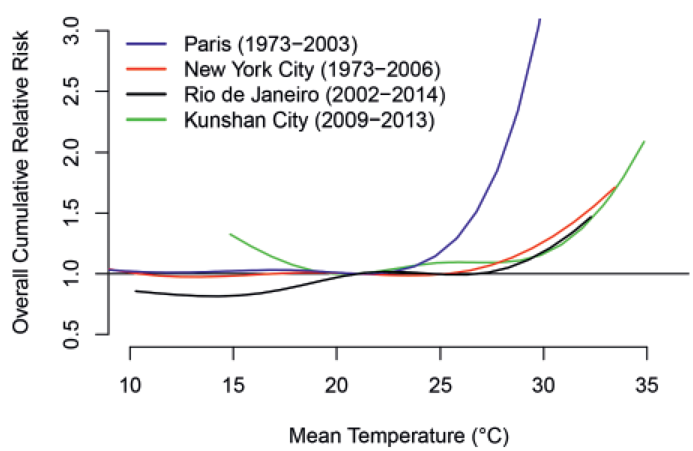

Figure 10.5 *Overall cumulative heat-mortality relationships in Paris, New York, Rio de Janeiro, and Kunshan City, China. Relative risks were calculated using a distributed-lag nonlinear model with a natural cubic spline with 4 degree of freedom for temperature and the lag, a maximum of 6 lag days, and 21°C as a reference temperature. Warm season (May–September) data for Paris (1973–2003), New York (1973–2006), and Kunshan City (2009–2013); November–March data for Rio de Janeiro (2002–2014).*

Source: Kai Chen and Patrick L. Kinney, with data from Surveillance Secretariat in Health from the Municipal Secretary of Rio de Janeiro

10.3.3 Vector-Borne Diseases

Many diseases are spread by vector organisms such as ticks and mosquitoes. Dengue and malaria are important mosquito-borne diseases contributing significantly to the burden of death and disease in urban areas in the developing world (Murray et al., 2012; Bhatt et al., 2013). Vector-borne disease incidence is influenced by temperature and precipitation, which can affect the range, prevalence, and reproductive cycle of disease vectors, among other determinants (Kelly-Hope et al., 2009). For example, trends in malaria in east Africa have been associated with warming trends observed there over multiple decades (Omumbo et al., 2011). There is evidence that the Lyme disease vector, the tick species *Ixodes scapularis*, has expanded its range from the United States northward into Canada over the past several decades in part due to warming temperatures (Ogden et al., 2008; Ogden et al., 2010).

Dengue fever transmitters, the *Aedes aegypti* mosquito, can be easily found in regions of tropical and subtropical climate, having an ideal temperature of transmission of between 23°C and 27°C, although temperatures from 18°C can also trigger its transmission. In contrast, temperatures below 5°C and above 36°C can impair and hinder the vectors' survival (Colón-González et al., 2013).

Climate change may lead to changes in the seasonal cycle and spatial distribution of some vector-borne diseases, although it is important to note that climate is only one of many drivers of vector-borne disease distribution (see Case Study 10.2). While climate change might lead to an expansion in the range of important disease vectors, it is also possible that optimal temperature conditions for certain vector species will be exceeded

Case Study 10.4 Health Impacts of Extreme Temperatures in Brisbane, Australia

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Keywords	Temperature, public health, years-of-life-lost
Population (Metropolitan Region)	2,065,996 (Australian Bureau of Statistics Census, 2011a)
Area (Metropolitan Region)	15,826 km² (Australian Bureau of Statistics Census, 2011b)
Income per capita	US$54,420 (World Bank, 2017)
Climate zone	Cfa – Temperate, without dry season, hot summer (Peel et al., 2007)

Brisbane is the third largest city in Australia, located on the Brisbane River, with its eastern suburbs by the shores of Moreton Bay. The greater Brisbane region is on the coastal plain east of the Great Dividing Range. The urban area is partially elevated by two large hills reaching up to 300 meters (980 ft), Mount Coot-tha and Mount Gravatt in the south. The city area covers 1,327 square kilometers, and the population was 992,176 in 2006. Brisbane is situated near the coast and has a subtropical climate. Summers are hot and wet, and winters are mild and dry.

In Australia, exposure to extreme temperatures has become a great public health concern over the past decade, largely because of numerous studies linking daily temperatures with daily mortality. Most previous studies were designed to examine temperature-related excess deaths or mortality risks. However, in previous analyses, deaths occurring on the same day were combined and differences in ages were ignored. Although some analyses stratified by several age groups, they treated all deaths as equally important within age groups.

To guide policy decision and resource allocation, it is desirable to know the actual burden of temperature-related mortality. Years of life lost is an indicator of premature mortality that accounts for the age at which deaths occurred by giving greater weight to deaths at younger ages. In comparison with mortality risk, years-of-life-lost is a more informative measurement for quantifying premature mortality. In this study, we conducted a time-series analysis to estimate years of life lost associated with season and temperature in Brisbane, Australia. We also projected future temperature-related years-of-life-lost under different climate change scenarios (Huang et al., 2012).

Daily mortality data on nonexternal causes from 1996 to 2004 were requested from the Office of Economic and Statistical Research of the Queensland Treasury. All deaths were residents of Brisbane city. These data included date of death, sex, and age. Years-of-life-lost were estimated by matching each death by age and sex to the Australian national life tables. The daily total years-of-life-lost were made by summing the years-of-life-lost for all deaths on the same day. Separate sums were made for men and women. The daily total years-of-life-lost contains information on the number of deaths and the characteristic of the deaths.

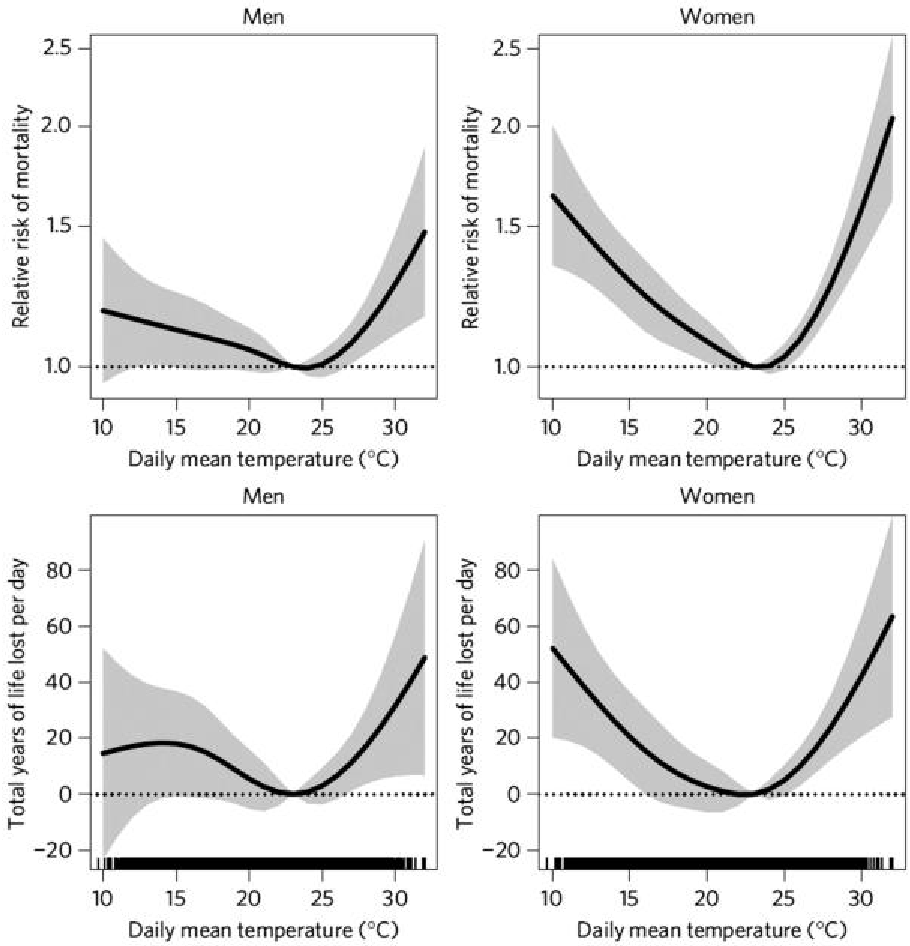
The Australia Bureau of Meteorology provided daily weather data. We used daily values of maximum temperature, minimum temperature, and relative humidity from the Archerfield station located near the city center. Maximum and minimum temperatures were the highest and lowest hourly measurements each day in degrees Celsius, with the mean temperature as their average. When data were missing for the Archerfield station (<2%), data from Brisbane Airport were used.

A regression model was used to estimate the association between daily mean temperature and years-of-life-lost, with adjustments for trend, season, day of the week, and daily humidity. To examine the nonlinear and delayed effects of temperature, we used a distributed lag nonlinear model. We plotted the mean and 95% confidence intervals for the years-of-life-lost against month and temperature.

The relative risk of mortality associated with changes in seasonality and temperature were estimated. We used the same independent variables as the years-of-life-lost model but with a dependent variable of the daily number of deaths, which we assumed followed a Poisson distribution. These results were intended to show the difference between a standard analysis of mortality and the analysis of years-of-life-lost.

According to the Intergovernmental Panel on Climate Change (IPCC), evidence for future temperature changes in variability is sparse, and the patterns of changes in extremes are shown in accordance with a general warming. Therefore, we assumed that climate change will cause increasing average temperatures but no change in variability. We simulated future daily temperatures by adding 1–4°C to the observed daily temperature data from 1996 to 2003. We used these 8 years as our baseline to reduce the influence of any unusual temperatures from any one year and because these data are centered on the year 2000. The increases of 1–4°C aimed to simulate daily temperatures in 2046–2053, centered on the year 2050.

The projected temperature-related years-of-life-lost in 2050 were calculated. The future health impacts were based on the nonlinear relationships between temperature and years-of-life-lost, separately for men and women. We assumed no human physiological



Case Study 10.4 Figure 1 *The effects of temperature on mortality risk and years-of-life-lost in Brisbane, Australia. The solid line shows the mean; gray areas show the 95% confidence intervals. The relative risk of mortality is shown in a log scale. The fine lines show the observed daily mean temperatures. The reference temperature is 23°C.*

acclimatization to higher temperatures. We also assumed that the population size, age structure, and life expectancy will remain constant, allowing the differences in years-of-life-lost to be those due to climate change. Estimates of the burden of heat-related mortality due to climate change can be somewhat offset by reductions in cold-related mortality. We therefore divided our estimates into heat- and cold-related years-of-life-lost.

We show that, in Brisbane, daily mortality has a strong seasonal pattern, with the highest numbers in winter (June–August) and lowest in summer (December–February). When using daily mortality counts, we observed a significant effect of season on mortality even after adjusting for daily temperature and humidity. However, there was no seasonal pattern in years-of-life-lost for both men and women. The association between temperature and years-of-life-lost is U-shaped, with increased years-of-life-lost for cold and hot temperatures. We also found comparable results for mortality risks, particularly in terms of the general U-shape and turning points (Case Study 10.4 Figure 1). Assuming a temperature increase more than 2°C but without any level of adaptation, large increases in heat-related years-of-life-lost are projected, and the increased heat-related years-of-life-lost will not be offset by decreased cold-related years-of-life-lost. This study highlights that public health adaptation to climate change is necessary.

and thus potentially reduce the risk of infection, particularly under high warming scenarios (Smith et al., 2014).

10.3.4 Water- and Food-Borne Diseases

Humans can be exposed to water- and food-borne pathogens through a variety of routes, including via the ingestion of polluted drinking water, consumption of contaminated food, inhalation of aerosols containing bacteria, and by direct contact with recreational or floodwaters. A number of pathogens that cause water- and food-borne illnesses in humans are sensitive to climate parameters, including increased temperature, changing precipitation patterns, extreme precipitation events, and associated changes in seasonal patterns in the hydrological cycle. While specific relationships vary by pathogen, increased temperatures appear to increase the incidence of common North American diarrheal diseases such as campylobacteriosis and salmonellosis (Curriero et al., 2001; European Centre for Disease Prevention and

Control, 2011; Semenza et al., 2012). Floods enhance the potential for runoff to carry sediment and chemical pollutants to water supplies (CCSP, 2008), and waterborne illnesses from exposures to pathogens and chemical residues from pesticide runoff (especially from freshly treated properties) in recreational waters have been shown to increase in the hours after extreme rainfall events (Patz et al., 2008). Risk of water-borne illness is greater among the poor, infants, elderly, pregnant women, and immune-compromised individuals (Rose et al., 2001; USGCRP, 2008).

Food and water scarcities impact human health. According to Sena (2014), drought is often a hidden risk and a potential silent public health disaster. It is difficult to identify precisely when this hidden health risk begins and ends because drought's impact on a population emerges gradually and depends on biological and social vulnerability. In the case of Brazil, half of all natural disasters are drought-related, and the effects of drought are largely concentrated in the semiarid Northeastern region of the country. Using available census data for 1991, 2000, and 2010, Sena (2014) found that the 1,133 municipalities most affected by drought (out of 5,565 municipalities in Brazil) were located in the Northeast region. Notably, health and well-being indicators for this region were worse than in the rest of the country. Current interactions between low social and environmental conditions will continue to be aggravated by climate change.

10.3.5 Air Pollution

It has been estimated that one in seven global deaths are related to air pollution, and a large fraction of these deaths result from exposures to fine particle components that also affect the climate (Lim et al., 2012. Short-lived climate-active pollutants such as ozone, methane, and black carbon contribute significantly to health burdens. Significant opportunities exist for improving urban health while also contributing to climate mitigation.

In addition, climate change has the potential to increase morbidity and mortality from respiratory and cardiovascular causes through its effects on air pollution. Emissions, transport, dilution, chemical transformation, and eventual deposition of air pollutants all can be influenced by meteorological variables such as temperature, humidity, wind speed and direction, and mixing height (Kinney, 2008). Ozone and particulate matter (e.g., particles with aerodynamic diameter <2.5 μm [$PM_{2.5}$] and <10 μm [PM_{10}]) are pollutants of particular concern due to their association with adverse health effects and their difficulty to control in the urban environment. Although air pollution emission trends for volatile organic compounds (VOCs) and nitrogen oxides will likely play a dominant role in future ozone levels, climate change will make it harder to achieve air quality goals (Jacob and Winner, 2009). Thus, we will need more aggressive reductions in VOCs and nitrogen oxides (NOx) to achieve ozone concentration targets.

Ground-level ozone is produced on hot, sunny days from a combination of NOx and VOCs, many of the sources of which also emit particles. NOx are emitted primarily by fossil fuel combustion. VOCs are emitted by fuel use as well as by vegetation. VOC levels are also high during surfacing and resurfacing of roads. This includes the traffic marking lines that are refreshed during warmer months when smog and ozone levels are highest. Ozone production is dependent on temperature and the presence of sunlight, with higher temperatures and still, cloudless days leading to increased production. Thus, ground-level ozone concentrations have the potential to increase in some regions in response to climate change (Ebi and McGregor, 2008; Tsai et al., 2008; Cheng et al., 2010). Although it has been noted that climate change could decrease ozone in remote areas with low levels of NOx, this is unlikely to be the case in urban environments, where traffic emissions are high. Exposure to ozone is associated with decreased lung function, increased premature mortality, increased cardiopulmonary mortality, increased hospital admissions, and increased emergency room visits (Dennekamp and Carey, 2010; Kampa and Castanas, 2008; Kinney, 2008; Smith et al., 2009).

$PM_{2.5}$ is a complex mixture of solid and liquid particles, including primary particles directly emitted from sources and secondary particles that form via atmospheric reactions of precursor gases. $PM_{2.5}$ is emitted in large quantities by combustion of fuels by motor vehicles, furnaces, power plants, wildfires, and, in arid regions, wind-blown dust. Because of their small size, $PM_{2.5}$ particles have relatively long atmospheric residence times (on the order of days) and may be carried long distances from their source regions. Research on health effects in urban areas has demonstrated associations between both short- and long-term average ambient $PM_{2.5}$ concentrations and a variety of adverse health outcomes including premature deaths related to heart and lung diseases (Schwartz, 1994; Samet et al., 2000; Pope et al., 2002).

Forest fire is a source of particle emissions and can lead to increased cardiac and respiratory disease incidence, as well as direct mortality (Rittmaster et al., 2006; Ebi et al., 2008; Jacobson et al., 2014). Studies of North American forest fires have demonstrated a link between climate change and the increased frequency and intensity of fires (Westerling, 2006). Although few urban areas are forested, the pollution emitted from wildfires can travel long distances and can affect respiratory health in urban centers. Simulation studies have predicted increases in ozone concentrations downwind of fire sites of between 10 parts per billion (ppb) and 50 ppb over eight-hour measurement periods (Pfister et al., 2008; Mueller and Mallard, 2011). Forest fires also exhibit potential synergistic effects on health when they coincide with heat waves, as occurred in Russia in 2010 (De Sario et al., 2013).

Changes in climate, such as temperature, humidity, and precipitation, also have the potential to alter the concentration and allergenicity of aeroallergens (pollen from trees, grasses, and weeds; and mold), as well as the length of their seasons (Sheffield et al., 2011; Ziska et al., 2011). Exposure to pollen has been associated with a range of allergic outcomes, including exacerbations of allergic rhinitis and asthma (Cakmak et al., 2002; Delfino, 2002; Villeneuve et al., 2006). Temperature and precipitation in the months prior to the pollen season affect production of many types of tree and grass pollens (Reiss and

Kostic, 1976; Minero et al., 1998; Lo and Levetin, 2007; U.S. Environmental Protection Agency [EPA], 2008).

In urban areas, the indoor environment can be a major source of exposure to airborne chemicals and aeroallergens. Climate adaptation measures, such as increased air conditioner use, and mitigation measures, such as building weatherization/energy efficiency measures, can have impacts on indoor air quality and human health. Bacteria and mold can grow in air conditioning systems. Air-tight buildings have fewer air changes per hour to rid the air of chemical contaminants from building materials, paints, sealants, cleaning agents, and more. Air conditioning tends to diminish indoor penetration of outdoor ozone and pollens, while tighter building envelopes can prevent the water intrusion and damage that contribute to mold growth but also reduce air exchange between indoors and outdoors, thus potentially increasing exposures to pollutants generated indoors, such as second-hand cigarette smoke, NO_2 from gas stoves, and indoor allergens. Strict air quality standards applied to emissions from the road transport sector can reduce fine PM concentrations with considerable gains in life expectancy (Harlan and Ruddell, 2011).

10.3.6 Climate Risks and the Urban Poor

Exposure to climate risks and health inequities are closely related. Poverty and poor health status are highly correlated, and growing economic inequality – whether as a result of climate change or other socioeconomic stressors such as rapid urbanization – will likely magnify the gulf between the health status of the wealthy and the poor (Satterthwaite et al., 2008; Smith et al., 2014; Walters and Gaillard, 2014). Poor people in cities commonly have limited access to healthy housing and high-quality health care (Satterthwaite et al., 2008), and essential public health services are themselves vulnerable to being adversely affected by climate variability and climate change (Frumkin and McMichael, 2008). Health outcomes for the urban poor often occur through indirect pathways: for example, rising food prices due to agricultural productivity losses are likely to disproportionately affect the urban poor who have no means of producing their own food (Porter et al., 2014).

Research on recovery from the Hurricane Katrina disaster, for instance, found that psychological distress, post-traumatic stress, and perceived stress were particularly elevated among low-income parents, mainly non-Hispanic black single mothers (Sastry and Gregory, 2013; Fussell and Lowe, 2014). Main drivers for this outcome were "indirect" correlates of the disaster, including household breakup, negative impacts on children, and living in severely affected dwellings and communities (Sastry and Gregory, 2013).

Poor people, particularly in low-income countries, are often highly reliant on informal health services, such as those provided by traditional healers, shopkeepers, and in the home. Reliance on these services may be beneficial or detrimental to health outcomes. Based on a comprehensive literature review, Sudhinaraset et al. (2013) found that informal health services are often the first choice for care in developing countries. This review outlined many health care problems potentially affecting the informal health sector, including inadequate drug provision, poor adherence to national clinical guidelines, and gaps in knowledge and provider practice; problems, however, were also found in the formal health sectors of these countries. Conversely, informal health networks may bolster social capital and thus aid post-disaster recovery in the case of climate-related disasters in urban areas (Aldrich, 2012). In New Orleans, for example, close-knit family relationships benefited a community that was devastated by Hurricane Katrina (Chamlee-Wright and Storr, 2011).

Last, it is worth noting that individual climate impacts do not always disproportionately affect the poor. The heavy 2011 landslides in Nova Friburgo (State of Rio de Janeiro) led to 177 confirmed leptospirosis cases and 937 confirmed dengue fever cases, and poor people were not found to be more susceptible than other social groups (Pereira et al., 2014b, 2014c) (see Case Study 10.2). The harmful effects of "ubiquitous" exposures such as dengue-carrying mosquitos and air pollution are also likely to be shared across socioeconomic strata. Using climate, mortality, socioeconomic, and pollution data for the cities of Bogotá, Mexico City, and Santiago, Romero-Lankao et al. (2013a) found that air pollution levels and socioeconomic vulnerabilities do not clearly correlate, affecting the poor and the wealthy alike.

10.3.7 Food Insecurity and Displaced Populations

Within urban areas there is often an enormous range in the level of access to nutritious foods, leading to unhealthy extremes of both under- and overnutrition. Climate change along with rapid urbanization may exacerbate food insecurity in cities that experience existing disparities. Poor urban consumers are extremely sensitive to price variations caused by climatic impacts on food production and/or distribution because they do often not produce their own food (Porter et al., 2014). Families may be forced to either limit the quantity or quality of food consumed, with strong potential impacts for human health. Children may be particularly affected by such impacts and suffer from wasting or stunting. In Box 10.4 we present examples of strategies of urban agriculture that are being implemented in Latin American Cities in order to feed poor families.

Urban areas are often the destination for people displaced from their rural livelihoods when drought leads to crop failures, with substantial potential for social disruption.

10.3.8 Role of Critical Urban Infrastructure in Supporting Population Health Following Extreme Climate Events

Many health hazards associated with extreme climate events in urban areas operate through disruptions in critical infrastructure. Lack of electricity can make it difficult or impossible to control the interior climate, refrigerate food, physically move about in high-rise buildings, pump water to upper floors, and operate medical support equipment (Beatty et al., 2006). These infrastructure disruptions can lead to a wide range of adverse health effects depending on the age, health status, and economic resources of residents in the affected households. For example, exposure to ambient heat or cold in the absence of climate control may lead to heat- or cold-related illness or exacerbate underlying chronic conditions. Carbon monoxide poisoning from backup generators or cooking equipment used improperly is another potential risk. Increases in overall mortality rates have been observed after widespread power outages (Anderson and Bell, 2012).

Storms can adversely affect power and gas delivery, transportation, communications and health care infrastructure, and food distribution systems, all of which are critical to maintaining the public's health in densely populated urban centers (Lane et al., 2013). Morbidity and mortality effects of heat, meanwhile, may be especially severe if a power outage (blackout) occurs during an extreme heat event. While a lack of air conditioning in homes increases the risk of heat-related death (O'Neill et al., 2005; Wheeler, 2013), air conditioning also contributes to higher power demand during heat waves, which increases the risk of power disruptions and blackouts. When blackouts occur, exposure to heat increases, with a corresponding increase in health risks. Blackouts can also increase risk of carbon monoxide poisoning from improper use of generators and cooking equipment. During August 2003, the largest blackout in U.S. history occurred in the Northeast. Although this particular blackout did not coincide with a heat wave, it occurred during warm weather and resulted in approximately 90 excess deaths and an increase in respiratory hospitalizations (Lin et al., 2011; Anderson and Bell, 2012).

Box 10.4 Contributions of Urban and Peri-urban Agriculture to Adaptation for Food Security, Nutrition and Health

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Latin America (LA) is characterized by high levels of urbanization, health disparities, and the highest inequity index in the world (World Bank, 2016). The gap between the rich and poor is widening within some LA cities in terms of income, access to health services, adequate housing, sanitation, food security, and nutrition. Climatic conditions have contributed to the increasing rural–urban migration trends occurring over the past 50 years in LA (IOM, 2014). High rates of urbanization in LA force the conversion of peripheral land into informal settlements for newly arriving migrants. These settlements are located in areas that lack infrastructure such as water and sanitation and adequate food supplies.

The exponential increase in urban populations, coupled with widening income disparities in LA cities, has eroded the ability of urban infrastructures to offer adequate food access to their populations, which affects nutrition and health. LA cities have the challenge of addressing the double burden of malnutrition; millions of people are undernourished, and there is an increasing trend in the number of obese who suffer from lifestyle-related chronic illnesses. The Americas is the region with highest obesity rates in the world (PAHO, 2014).

There are many potential contributions of urban and peri-urban agriculture and forestry (UPAF) to climate mitigation and adaptation for food security, nutrition, health, and well-being in LA cities. UPAF can play a strong role in enhancing food security and nutrition for the urban poor, greening the city, improving air quality, lowering temperatures, stimulating water storage and drought resistance, reusing urban organic wastes, and reducing the urban energy footprint (Prain and Dubbeling, 2010). Several cities in LA have already promoted or engaged in these type of initiatives.

For example, in Lima, Peru, a city-level policy adopted in 2012 supports urban agriculture. It is included in the municipal development plans, which set up special municipal structures and budget allocation to urban agriculture (FAO, 2014). In Lima, urban agriculture is widely practiced at different scales and for multiple reasons. Commercial horticulture and livestock production take over in the peri-urban and transition areas. In the intra-urban areas producers grow mostly vegetables and small livestock. Many of the low-income households on the hillsides also raise chickens, guinea pigs, and pigs, mostly for local sales and for home consumption. Beyond the contribution to food security, there are psychological benefits of having one's own food production (Prain and Dubbeling, 2010). Women producers in Lima have the perception that by growing their own food they were caring for the environment as well as for their own and their families´ health by eating fresh and non-contaminated foods. They also consider the physical activity in itself healthy and contributing to their sense of well-being and relaxation. In this sense, they feel that urban agriculture is enhancing their quality of life (Prain and Dubbeling, 2010).

In Managua, Nicaragua, the success of urban agriculture is focused on water availability. Because the rainy season occurs strictly between May and November, the remainder of the year sees little precipitation. This discrepancy challenged the community in developing their backyard urban gardens. Within Managua, Los Laureles Sur is a community with high rates of both food insecurity and malnutrition, with an average of fruit and vegetable consumption of 60 g per capita per day (15% of recommended consumption levels by FAO and WHO); thus, it was targeted as an important place to integrate urban agriculture. In combination with a training program, rooftop rain collection systems were installed in homes to capture and store water for use during the dry months; this program was extremely successful to improve nutrition through healthier diets (FAO, 2014). This rainwater collection system helped boost urban agriculture in the city to improve average vegetable consumption by 60% (FAO, 2014).

In Mexico City, one specific success in urban agriculture was accomplished in conjunction with government and private organizations to create green rooftops across Mexico's urban areas. These green rooftop spaces support hydroponic gardens where the growth of succulents help reduce the impacts of air pollution in a city suffering daily from poor air quality (FAO, 2014). The program has been quite successful: more than 12,300 square meters of city rooftops have been converted to green urban gardens. Additionally, within the heart of the city, the Huerto Romita, a 56 square meter gardening center, was created to promote and provide an area for community urban vegetable production. The Huerto Romita center also functions to teach garden maintenance techniques and helps to install gardens in schools and throughout the community (FAO, 2012), contributing to food and nutrition security.

In Rio de Janeiro, urban agriculture pilot programs have provided blueprints for working inside fragile communities, for reutilizing abandoned lands, for remediating degraded space, for increasing food and nutrition security, and for generating income (Rekow, 2015). Being able to cultivate or play in a garden is one of the most profound and therapeutic experiences available when living in a dense urban favela. The ability to congregate in an aestheticized, productive public space and pick produce to take home is testimony to the enormous difference that food security programs are making in the daily lives of at least some residents living under pacification in Rio de Janeiro's inner-city slums (Rekow, 2015).

The everyday basic infrastructure deficiencies of informal settlements such as slums, meanwhile, can exacerbate the health impacts of disasters in these highly populated areas. Outbreaks of water-borne infectious diseases are one health concern of particular importance in slum areas, where crowding and poor sanitation are prevalent (OMS, 2012; Freitas et al., 2014).

10.4 Adaptation Strategies to Protect Health in Cities

The question of how to facilitate urban adaptation to climate change health impacts quickly leads into issues of understanding what the likely impacts are and how they might best be managed in specific urban settings. In turn, the answers to these questions feed into the planning processes and management strategies that can help cities increase their resilience to threats from climate change. In addition, understanding the multidimensional aspects that confer population vulnerability to climate extremes is essential for effective and long-term sustainable adaptation because it provides elements for the formulation of adaptation strategies for protection in relation to the expected impacts (Confalonieri et al., 2014).

One important consideration throughout is that cities are complex systems. They have many distinct components with a wide range of potential interactions, and these components self-organize over time and exhibit behavioral patterns that emerge from these diverse and complex interactions (Batty, 2008). This complexity influences what health impacts are likely to emerge, how they might be detected, and how they might best be managed. Recognizing and exploring this complexity can also help clarify what management strategies may be most effective and may highlight knowledge gaps that can be filled through modeling, targeted learning, and other strategies.

Case Study 10.5 Kedarnath: Flood and Humanitarian Loss in Uttarakhand Districts in India

Thea Dickinson

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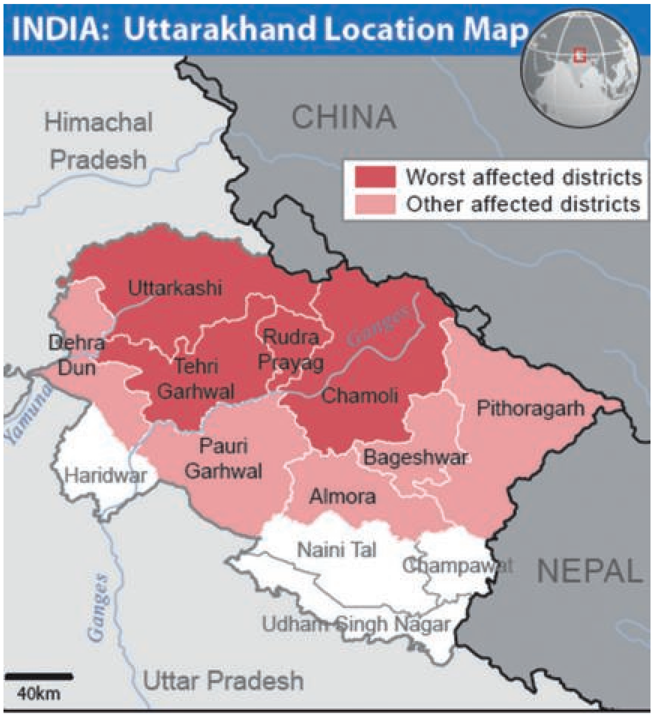
Keywords	Flood, monsoon, rainfall, extreme event, health
Population (Metropolitan Region)	10,116,752 (Census Bureau of India, 2011)
Area (Metropolitan Region)	53,484 km^2 (Census Bureau of India, 2011)
Income per capita	US$1,680 (World Bank, 2017)
Climate zone	Csa – Hot-summer Mediterranean (Peel et al., 2007)

The second largest humanitarian disaster in 2013 occurred in thirteen cities in Uttarakhand, North India, with the town of Kedarnath being the most impacted by the flood. It illustrates how many developing countries are not yet well prepared for the interconnected and cascading impacts of climate change. During June 2013, tens of thousands of people were on a pilgrimage when the monsoon rains began. Kedarnath lies on the southern slope of the Himalayas, and the land traversed by the pilgrims is almost entirely mountainous, with more than 60% covered in forest. The rains that fell in June 2013 were stronger than in the 80 years prior, surprising pilgrims and tourists by arriving earlier in the season than expected. The rains fell for 50 hours and produced more than 500 millimeters of total precipitation in the cities of Uttarakhand (Munich Re, 2014; Dube et al., 2013; Dube et al., 2014)); this was 374% above normal monsoon precipitation of 65.9 millimeters (Anumeha et al., 2013). This triggered a catastrophic chain of events. Snowmelt, including from the retreating Chorabari Glacier, added to the heavy precipitation, causing glacial lake outbursts and flooding the Mandakini river. Water levels in the



Case Study 10.5, Figure 1 *An early start to the 2013 monsoon rains led to severe flooding in Uttarakhand, India.*

Source: UNCS, GAUL, Natural Earth

cities increased by upwards of 7 meters, leading to catastrophic flooding, erosion, and landslides.

Landslides and flood waters trapped 75,000 pilgrims in Kedarnath. A reported 5,748 lives were lost and hundreds of others were sickened with gastroenteritis from water-borne disease due to contaminated spring water and groundwater contamination in broken pipelines.

In the past few decades, the government has increased development in areas along the popular Himalayan pilgrimage routes. Natural forest cover has been reduced in order to build roads and dams, thus decreasing the stabilization of mountains. Infrastructure, plans and policies, and early warning detection systems to prevent such calamities are either lacking or underdeveloped. These factors led to increased vulnerability to extreme events. The resulting 7 meter floodwaters caused not only losses to property, schools, health centers, hydroelectric power stations, city infrastructure, cash crops, and fisheries, but also claimed the lives of 6,054 locals and tourists. A total of 504,473 people were injured and/or displaced. Economically, the overall losses were estimated at $1.5 billion with only $600 million covered in insured losses.

In the wake of the June floods, the government announced a new water policy: the Uttarakhand Water Management and Regulatory Act, which came into effect on April 4, 2014. Because flood events are expected to increase with a changing climate, this Act is intended to improve the management of future risks from water-related gastrointestinal illnesses.

The Act:
- Provides for the establishment of a Water Management Regulatory Authority to ensure judicious and equitable management of water resources in the state as well as its proper allocation and optimal utilization.
- Creates a five-member authority with the powers of a civil court and the mandate to carry out developments in the state in an eco-friendly and sustainable manner.
- Devises a new water policy to manage rivers.
- Fixes rates for water use for industrial, drinking, power, agricultural, and other purposes, fixes and taxes on land benefited by flood protection and drainage works.
- Deters construction on surface recharge areas and improves tourism plans (because flooding deterred tourism) (Indian Express, 2013)

As in Calgary (see Case Study 10.A in Annex 5), the many layers of vulnerability magnified the impacts of this event: a shifting monsoon season, lack of government intervention, and substantial changes to land use. All these factors converged to create catastrophic – and perhaps somewhat preventable – loss of life. The new Act provides a step in the right direction, but it needs to be implemented along with other no-regret policies and actions that consider climate change while providing co-benefits to the region's residents and protecting tourists when they visit.

10.4.1 Understanding Health Risks and Possible Responses

Cities are developed with an unspoken assumption of a stationary climate – an assumption made invalid by climate change. As a result, most cities are at baseline not well adapted to the threats that climate change is likely to pose. Increasing resilience in urban areas means focusing on the strategies, policies, and measures needed to address the (1) considerable existing adaptation deficit and (2) modifications needed to current and newly developed policies and measures to manage these projected health risks. Doing so requires consideration of how health risks could change over temporal and spatial scales and of the other sectors whose activities could potentially enhance or harm population health. Effective and efficient adaptation requires a multisectoral and multigovernance response (Bowen et al., 2012).

Urban health risks of climate change relate to the natural and built environment, to the population's exposure to climate change hazards, and also to the ability of individuals and institutions to prepare for, cope with, respond to, and recover from the exposure (IPCC, 2012; NRC, 2012). Therefore, careful investments in infrastructure and environmental and health care systems must be applied (Barata et al., 2011). Adaptation measures tend to focus on one of these factors, with the particular concerns depending on the health outcome of concern. For example, an approach focused on preventing *exposure* to storm surges and associated flooding may be effective for reducing the resulting adverse health effects in some coastal urban populations (Solecki et al., 2010). Some other health impacts, such as outbreaks of climate-sensitive vector-borne and zoonotic diseases, may necessitate a multisectoral approach to disease surveillance and control, as was seen with an outbreak of West Nile virus in Texas: the outbreak was associated with weather patterns, geographic characteristics, and historic hotspots for vector activity (Chung et al., 2013). Even when a narrow emphasis may be efficient and expedient, it is important to note that this has the potential to compromise risk management when there are assumptions of full functionality in other domains. For example, an approach focusing on air conditioning as a preventive measure for reducing heat-related morbidity and mortality is vulnerable to failure when the underlying infrastructure – the electrical grid – weakens or fails during a summer heat wave (Anderson and Bell, 2012).

In addition to understanding the likely health effects of climate change in a given urban environment, it is important to understand how health care services are delivered and to consider other major factors that affect population health status. Among them are the cumulative health risks to vulnerable urban populations from multiple climate change-exacerbated exposure; one example is the long-term diminishment of resilience among U.S. Gulf Coast communities after repeated storms, flooding, displacement, and storm-related pollution.

10.4.2 Planning a Response to Health Risks

The processes of designing, implementing, monitoring, and evaluating health adaptation options are similar to those used in other sectors. Several health adaptation assessment guidelines (e.g., WHO, 2011; ECDC, 2011; Health Canada, 2011) all share similar features. Although these are not focused on urban areas, the process is the same. Figure 10.6 is an example of the process for conducting a vulnerability and adaptation assessment developed by the WHO.

One novel strategy may facilitate planning processes at the urban level. Carlsson-Kanyama and colleagues employed a novel back-casting approach to develop adaptation case studies in Swedish cities and identified several potential barriers to adaptation at the municipal level (Carlsson-Kanyama et al., 2013). They found strong interdependencies related to water supply and quality, energy, the built environment, and services and care for elders. Importantly, their research supported the contention that effective adaptation is contingent on strong intersectorial communication, a prominent theme in climate change adaptation. Their methods may be useful for other regions looking to strengthen municipal climate change adaptation efforts specifically.

Much of the current focus of health adaptation policies and measures (in urban environments and otherwise) is on increasing health protection in a changing climate, such as increasing resilience to the current pattern of extreme weather and climate events (Lesnikowski et al., 2013). The attention of most adaptation efforts has been on strengthening existing policies and

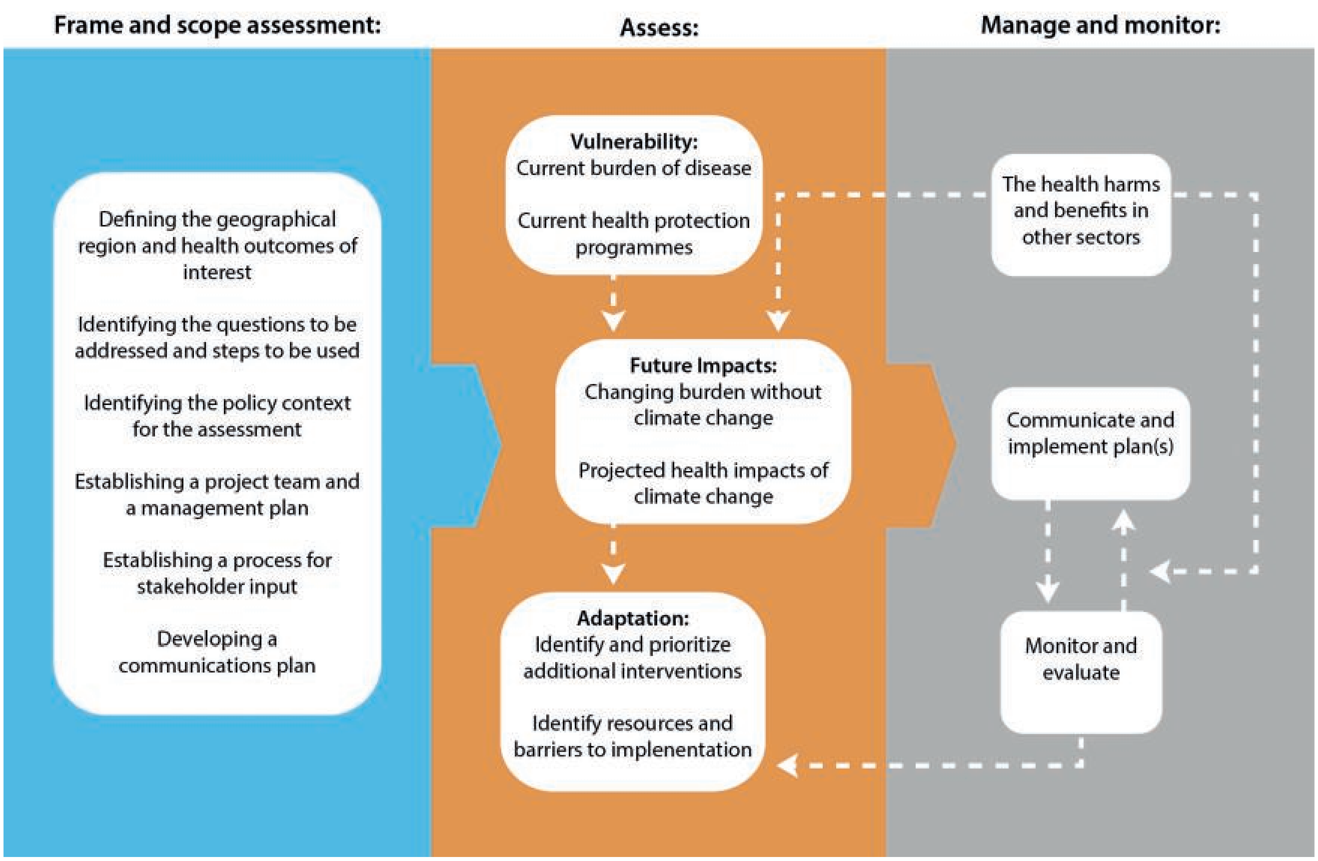


Figure 10.6 *Process for conducting a vulnerability and adaptation assessment in cities.*

Source: WHO, 2011

measures to address current weather patterns (e.g., early warning systems; ensuring vector-borne disease control programs incorporate information on recent changes in temperature and/or precipitation). However, these efforts may not be sufficient as climate change progresses (Kates et al., 2012).

A major impediment to planning a response to the health risks of climate change is a shortage of evidence that can be used to determine the effectiveness of particular adaptation strategies in the face of climate change. That is, we lack a sense of public health's coping range to address the hazards associated with climate change. A systematic review of public health interventions related to vector-borne diseases, water-borne diseases, and heat stress assessed the strength of evidence for addressing climate change risks (Bouzid et al., 2013). The interventions evaluated included environmental interventions to control vectors, household and community water treatment, greening cities, and community advice. Overall, the quality of evidence for the positive impacts of environmental interventions was low, owing both to poor study design and to high heterogeneity among study results. Furthermore, for some extreme weather and climate events (floods and droughts) and for food safety there were no satisfactory systematic reviews of public health interventions. These are clearly priority areas for additional research and evaluation. In terms of the evaluated interventions, in some cases, there may merely be insufficient evidence to make a determination of an intervention's effectiveness. The greater concern, however, is that the evidence available suggests a general lack of effectiveness of existing adaptation strategies. This could become a significant public health concern if hazard intensity increases as expected.

A strategy that has met with some success in other sectors is adaptive management, a structured, iterative process of decision-making in the face of imperfect information (Ebi, 2011; Hess et al., 2012). Adaptive management recognizes the uncertainties associated with projecting future outcomes and considers a range of possible future outcomes when formulating interventions. It also explicitly incorporates models of complex systems to support decisions and requires regular updating of models to support institutional learning and iterative decision-making, both of which can facilitate effective management of complex systems. In an adaptive management approach, interventions are intended to be flexible, taking into account various stakeholder objectives and preferences, and must be subject to adjustment in an iterative, social learning process. Identifying best practices from experiences with using adaptive management approaches would help urban areas as they augment current policies and measures to address the health risks of climate change.

10.4.3 Management of Health Risk and Adaptation Strategies

Management of climate change adaptation strategies includes implementation, monitoring, and evaluation (Moser and Ekstrom, 2010). As noted, much adaptation activity to date has been located at the national level and has been in the planning stage, although implementation is now under way in several areas.

A survey of European countries on health adaptation identified measures being taken to strengthen health systems to manage the health risks of climate change (Wolf et al., 2014). In this survey, representatives of the working group on health in climate change in the WHO European Member States were interviewed to address the question "How far are we in implementing climate change and health action in the WHO European Region?" Twenty-two Member States provided answers to a comprehensive questionnaire that focused on eight thematic areas, with the countries scored on their performance in each: the maximum score was reached by 16 countries in governance; 17 in conducting vulnerability and adaptation assessments; four in developing adaptation strategies and action plans; four in reducing GHG emissions; seven in strengthening health systems; six in raising awareness and building capacity; five in greening health services; and six in sharing best practices. These results indicate considerable possibilities for improvement.

Adaptation should fit within country and city development goals to increase the likelihood of success and of securing the necessary human and financial resources. Panic and Ford (2013) reviewed national-level adaptation planning for infectious disease risks in a changing climate in 14 countries of the Organization for Economic Cooperation and Development (OECD) (Australia, Belgium, Canada, Chile, France, Ireland, Luxembourg, Mexico, New Zealand, Slovenia, Spain, Switzerland, the United Kingdom, and the United States). Although the adaptation plans varied widely, in general, adaptations were mainstreamed into existing public health programs, indicating that the plans fit into health sector planning. However, the plans did not prioritize multidisciplinary approaches that indicate that opportunities to ensure adaptations implemented in sectors such as water and energy also promote population health. Further limitations were negligible consideration of the needs of vulnerable population groups, limited emphasis on local risks, and inadequate attention to implementation logistics, such as available funding and timelines for evaluation.

As a welcome departure from the largely nationally focused planning that has traditionally been exercised to date, three multicountry health adaptation projects covering fourteen low- and middle-income countries are completed or nearing completion. They are:

- Barbados, Bhutan, China, Fiji, Jordan, Kenya, and Uzbekistan[2] in a UNDP/WHO GEF project "Piloting Climate Change Adaptation to Protect Human Health"
- China,[3] Jordan,[4] and the Philippines[5] in the health components of the Millennium Development Goals (MDG) Achievement Fund

2 http://www.who.int/globalchange/projects/adaptation/en/
3 http://www.mdgfund.org/program/chinaclimatechangepartnershipframework
4 http://www.mdgfund.org/program/adaptationclimatechangesustainjordan%E2%80%99smdgachievements
5 http://www.mdgfund.org/program/strengtheningphilippines%E2%80%99institutionalcapacityadaptclimatechange

- Albania, Kazakhstan, Kyrgyzstan, Macedonia, Russia, Tajikistan, and Uzbekistan[6] in the WHO EURO project "Protecting Health from Climate Change: A Seven-Country Initiative" funded by the International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

Although few of the specific activities within these projects focused on urban areas, they considered issues that are of high relevance to urban areas, such as access to safe water and the possible geographic spread of vector-borne diseases. The lessons learned and best practices from these projects will provide valuable guidance for health adaptation in urban areas.

Progress is also being made in many regions concerning data exchange and cross-national disease surveillance. For example, the European Centre for Disease Control and Prevention (ECDC) is promoting integrating surveillance for infectious diseases through its European Environment and Epidemiology (E3) Network (Semenza et al., 2013). The E3 portal (http://E3geoportal.ecdc.europa.eu/) supports data exchanges and sustained collaborations between European Union Member States, researchers, and other interested collaborators to, among other aims, provide technical support for the reporting, monitoring, analysis, and mapping data, as well as to enhance the analytical capacity of existing resources in Europe. Such a resource will be helpful to urban areas in Europe and will provide best practices and lessons learned to urban areas in other regions as they augment surveillance programs to include the risks of climate change.

Monitoring and evaluation are important aspects of management and strengths in public health generally, although, as noted, public health does not always invest in developing a strong evidence base as much as it might want, and there has been relatively little use of cluster-randomized trials and other available tools to evaluate potential adaptation activities. Public health has extensive experience with disease surveillance, however, and this experience can be leveraged to facilitate climate change adaptation (Frumkin et al., 2008). Surveillance activities are key to establishing trends in climate-sensitive diseases that might serve as indicators of shifts in population health as a result of climate change (McMichael, 2001). Evidence-based public health is an increasingly important tool for assessing the effectiveness of interventions and for facilitating the dissemination of effective practices (Knowlton et al., 2014).

Vulnerability mapping is an efficient tool for planning the implementation of transitional adaptation measures in cities (Frumkin et al., 2008) as well as monitoring and evaluating its results. Examples are presented in the Case Study Docking Station Annex (see Case Study 2.B and Case Study 3.B in Annex 5).

Romero-Lankao et al. (2012) applied a meta-analysis of 54 papers looking at urban vulnerability to temperature-related hazards, covering 222 urban areas globally. They found that the vast majority of papers focus on the epidemiological linkages between temperature and mortality, with very few attempting to understand the structural mechanisms determining differences in vulnerability to temperature-related hazards within and across communities and cities (Romero-Lankao et al., 2012). In the United States, Reid et al. (2009) mapped a set of proposed community determinants of vulnerability to heat. The factors explaining most of the difference, among a large group of potential variables, were (1) a combination of social and environmental factors (2) social isolation (3) prevalence of air conditioning, and (4) the proportion of elderly and diabetics in the population. The map Reid et al. (2009) produced helps the public health sector identify areas likely to contain residents at greater risk of the adverse health consequences of heat.

10.4.4 Applying Urban Adaptation Strategies to Protect Human Health

Because each city and its populations are unique and the dynamics of climate change are complex, the process of health adaptation planning must be tailored and flexible to make necessary adjustments, especially considering the uncertainty in a long-term perspective. Furthermore, because resources are limited in developing countries, planning for these important and growing urban aspects may require new and innovative approaches. City authorities are willing and able, but they need timely information on long-term trends, potential tipping points, and possibilities for surprise. Integration of mitigation and adaptation measures into broader development goals may be particularly relevant in this respect (Rosenzweig et al., 2010).

Complex thinking stresses that the development of a plan that anticipates all future climate-related hazards and their associated impacts on human well-being represents a challenge. Instead, incremental efforts need to be tried and tested in different cities of the world. Implementing and evaluating diverse projects will increase understanding of how best to improve urban health outcomes in specific contexts (Rydin et al., 2012). Nevertheless, a recent global study of 468 member communities of the ICLEI—Local Governments for Sustainability network found that health concerns rank relatively low on a list of perceived climate impacts (Carmin et al., 2012b).

Smith et al. (2014) suggest that the most effective adaptation strategies for health in the near-term are measures that improve basic public health and health care services, employ technology to promote the adoption of effective policies, and aid in implementing early warning systems.

6 http://www.euro.who.int/__data/assets/pdf_file/0019/215524/PROTECTING-HEALTH-FROM-CLIMATE-CHANGE-A-seven-country-initiative.pdf

In Latin America and the Caribbean, countries that have been impacted by extreme events have instituted building safety codes in line with the specific threats characteristic of their regions (Centro Regional De Información Sobre Desastres [CRID], 2009). Local health institutions are also proactively conducting vulnerability studies. For example, Chile and Mexico have both used the Pan American Health Organization's (PAHO, 2009) hospital security index: low-cost, rapid means of evaluating whether a given health institution could cope in a disaster. In addition to this, there is also an initiative called SMART hospitals, which aims at making hospitals resilient to disasters, but which also adds a mitigation component of measuring and reducing their GHG emissions. Pereira et al., 2014a presents the experiences of Latin American countries regarding the preparation and adaptation of the health sector to climate changes.

Relevant adaptation strategies for the protection of citizens' health in urban areas must also include the strengthening of all oversight programs. Good governance should include efforts to integrate a concern for public health into all programs, plans, and projects on the municipal level (Smith et al., 2014). For example, the City of Toronto identified the interdependencies of infrastructure, services, and priority populations as a key challenge to developing and adopting effective and equitable climate adaptation actions (City of Toronto, 2014). Through a cross-corporate working group, and by reaching out to individual city divisions, Toronto Public Health (TPH) encourages health and equity to be considered in a range of municipal climate adaptation and mitigation policy and program decisions. Developing strong partnerships and identifying health co-benefits of climate adaptation and mitigation actions led to outcomes such as a pilot project to reduce vulnerability to heat in multiresidential settings, use of heat vulnerability maps developed by TPH to inform decisions about where to do new tree-planting in the City (Toronto Public Health [TPH], 2011), and support for TPH's ongoing role in supporting sustainable transportation systems (e.g., TPH, 2014a, 2014b).

Other sectors, including food and water distribution, ecosystem services, infrastructure, energy and transportation, and land-use management, also play important roles in determining the urban risk of disease and injury resulting from climate change (Smith et al., 2014).

Implementing basic measures that improve citizens´ health quality, such as the provision of clean water and sanitation as well as the reduction of flooding and poverty in cities, is relevant to reduce diseases related to climate change. Projecting climate-sensitive disease will likely play an important part in adaptation strategies, such as efforts to do seasonal forecasts of dengue vector incidence, which could help detect possible incidences months in advance of their actual occurrence.

Two Case Studies in the ARC3.2 Case Study Annex (Annex 5) present the consequences of heavy rainfall and floods on human health in urban centers. They are Case Study 10.A, "Economic Cost and Mental Health Impact of Climate Change in Calgary, Canada" and Case Study 10.C, "City of Toronto Flood: A Tale of Flooding and Preparedness." Case Study 10.5, "Kedarnath: Flood and Humanitarian Loss in Uttarakhand Districts in India," also provides another example. A comparative analysis of those three cases shows that in Uttarakhand districts, 6,054 people died and 504,473 people were evacuated because of the flooding caused by heavy rainfall. Similar events occurred in the cities of Calgary and Toronto in Canada, where preventive adaptation strategies were well implemented. In particular, 50,000 people in 26 communities were evacuated. Mental health illness was the reported consequence in Calgary, and the loss of well-being and potential food-borne disease was the health consequence in Toronto. In addition, property damage and economic loss caused by the heavy rainfall and flood were reported.

10.5 Mitigation Strategies and Co-Benefits

As we saw earlier, human health is at risk from climate change in many ways. Mitigating climate change by reducing GHG emissions will therefore deliver health gains, indirectly and in the long term, by containing these increased risks (Haines et al., 2009). However, there are more immediate health gains that can result in the short term through actions aimed at mitigation – these are the so-called "health co-benefits" of action on climate change. We consider these first, then move to the reverse: the beneficial effects on the environment of steps taken primarily to improve health.

10.5.1 Health Co-Benefits of Mitigation

Wherever a policy aimed at climate change mitigation also directly benefits health, the reverse is also true: if the same policy is adopted primarily for its health benefits, it will also mitigate climate change. An important example is the promotion of low-GHG diets. Useful reductions in GHG emissions can be achieved by reducing consumption of red meat, especially beef. This is for two reasons: first, the operation of the beef industry is itself very energy-intensive in water use, fertilizer, and transport; second, the digestive process in ruminants releases methane, the second most important GHG. Reducing beef consumption in favor of other foods is therefore an available mitigation strategy, but it also brings well-known health benefits through reductions in obesity, cardiovascular disease, and colon cancer (Friel et al., 2009). These health benefits can be a co-benefit of policies and actions aimed primarily at mitigation. This double gain can also be looked at the other way: reducing meat consumption for health reasons, whether through individual choice or through public health policy initiatives, will bring mitigation co-benefits through reducing emissions.

Similarly, implementing active transport strategies can reduce both GHG emissions and heart disease (Woodcock

Case Study 10.6 Kunshan Eastern Health Care Center, Kunshan City, China

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Keywords	Green technology, energy efficiency, water conservation.
Population (Metropolitan Region)	1,970 million (Demographia, 2016)
Area (Metropolitan Region)	557 km^2 (Demographia, 2016)
Income per capita	US$8,260 (World Bank 2017)
Climate zone	Cfa – Warm temperate, fully humid, hot summer (Peel et al., 2007)

The city of Kunshan lies 37 kilometers west of Shanghai in the Yangtze River Delta area of China. With a population approaching 2 million, including migrant workers, and a gross domestic product (GDP) of US$32 billion (2010), it is the single richest county in China and aspires to Western standards of education, industry, and health care.

To provide health care services for its growing population, Kunshan is building three new health care facilities. A new hospital in the east of the city will provide Western medical services. A second new hospital to the west will deliver traditional Chinese medicine, whereas the third center will house the Kunshan Center for Disease Control and Prevention, Health Authority, Red Cross blood banks, health promotion centers, and maternal and child health services.

Kunshan is investing in green technology as part of this next stage of its economic development. The Eastern Health Care Center will include a new 1,200-bed hospital, designed by an international consortium from Scandinavia. Its modular construction, materials, and air system are designed to reduce energy consumption both during construction and in operation, thus contributing to climate change mitigation through reduced greenhouse gas emissions.

Efficient heating will be achieved by recycling heat from shower water, supplemented by solar panels. Passive cooling will be achieved by circulating water to nearby lakes.

The hospital has also been designed to be water-efficient, using 70% less water than hospitals currently operating in China. As one strategy to achieve this, the hospital will use a centralized vacuum system for flushing toilets, similar to aircraft systems. The system will use 1.2 liters per flush instead of the 6 liters that is the U.S. Environmental Protection Agency's current efficiency baseline, an 80% reduction. Note that the LEED-2009 guideline is only for a 20% reduction (U.S. Green Building Council, 2010). This will reduce the dependence of the hospital on the city's water supply, increasing its resilience to extreme events, especially drought and flood. It also reduces the need for power-demanding ventilation, reduces hazardous waste storage, and reduces the risk of infection.

As one of the largest public buildings in Kunshan, this new hospital complex will set a standard in environmentally sensitive design and advanced green technology for the city, helping Kunshan follow a sustainable development path.

Case Study 10.6, Figure 1 *Kunshan Eastern Health Care Center.*

et al., 2009; Silva et al., 2012; Patz, 2014). Reducing domestic and industrial coal-burning in and around cities will reduce dangerous black carbon pollution in the air: but suspended carbon particles also contribute to global warming, so reducing particle emissions also mitigates climate change (Smith et al., 2009; Humphreys, 2014; Fleck, 2014). Policies motivated by either of these two gains will bring benefits in the other.

In considering mitigation strategies that can aid health, we should not overlook the health system itself. Hospitals are important consumers of energy, so gains in energy efficiency in hospitals can benefit the environment through energy conservation and also benefit the health of populations through cost savings to the health system (U.S. Energy Information Administration, 2007). As part of the America's Climate Action Plan, the U.S. Department of Health and Human Services has created a "Sustainable and Climate Resilient Health Care Facilities Initiative." This initiative includes a guide to enhancing resilience in the health sector.[7] In China, the Kunshan Hospital case study is another example (see Case Study 10.6).

These considerations strengthen the case for longer term climate change mitigation by pointing to additional current-day benefits to society, health co-benefits that can arise from mitigation policies. These health benefits would apply even in the absence of climate change, providing "no-regret" strategies that can be defended as being of value regardless of what view is taken of future climate change.

Finally, the health benefits may be delivered explicitly through climate change mitigation policies if public money is diverted from climate-damaging fuel subsidies and instead put toward enhancing national health systems (Yates, 2014).

10.5.2 Co-Benefits of Adaptation

Mitigating climate change by reducing GHG emissions will not be sufficient to eliminate the impact of climate change. Faced with the inevitability of climate change, cities and individuals must adapt to protect their health and livelihoods. Here again, the principle of co-benefits applies: policies and individual choices aimed at protecting health can also have co-benefits in the sense of mitigating climate change.

For example, an important step that cities can take to reduce the adverse health impact of climate change is to reduce the intensity of their urban heat islands (UHI). Cities are well known to be significantly warmer than the surrounding countryside due to the heat capacity of their buildings and roads and the relative lack of cooling provided by vegetation and open water. Green city policies, such as tree-planting and the provision of open water within cities, will therefore go some way toward reducing inner-city temperatures, and this is an important option for adaptation to climate change (see Case Study 10.B in Annex 5). White roofs and light-colored roads also help (Rosenzweig et al., 2006). However, such initiatives will also yield benefits for climate change mitigation in several ways: (a) reduced temperatures in summer will mean reduced use of air conditioning, with reduced energy consumption and hence reduced GHG emissions; (b) the improved inner-city amenity will encourage active transport, reducing fuel use.

A second type of adaptive action is to increase the health of the population generally, thereby increasing its overall resilience to environmental threats like heat waves. After smoking, the greatest threat to urban health in both developed and developing countries is obesity. Actions to reduce levels of overweight include reduced calorie intake (derived from meat and other sources) and increased exercise, with active transport (walking/bicycling) forming an important component of everyday movement. Both these approaches will also reduce GHG emissions and thus have mitigation co-benefits in addition to their primary, direct health benefits.

10.5.3 Unintended Consequences

It is not all good news. Mitigation actions may have unintended, detrimental side effects on health, such as energy price increases that, while intended to reduce emissions, also make it harder to heat and cool homes. Actions aimed at health adaptation can be expensive in GHG emissions, such as increased use of air-conditioning: clearly protective of human health in cities at risk of heat waves, air conditioning is a massive consumer of electricity, leading to increased GHG emissions and accelerated climate change.

The case for a local climate change adaptation plan is less compelling if it merely moves the problem elsewhere. It might appear that electric transport, both individual (e-bikes) and mass (trains), delivers benefits both in terms of reduced GHG emissions and improved urban air quality. But if the electricity is generated by burning fossil fuels at remote power stations, it is important to weigh the benefit of this policy against the cost of both the GHGs and of the air pollution generated by the power stations.

10.6 Barriers and Bridges to Mitigation and Adaptation

Although mitigation and adaptation activities are beneficial to citizens' health, there are also barriers to their implementation. These barriers include:

- *Limited institutional capacity*: Unclear/unhelpful administrative boundaries, lack of sufficient knowledge, concentrated expertise (often in marginalized environmental departments), and lack of financial and human resources (Bulkeley, 2010)
- *Lack of local government resources* and very limited capacities to invest (e.g., when the majority of local revenues go toward recurrent expenditures and/or debt repayment)

7 http://toolkit.climate.gov/image/662

- *Difficulty and/or reluctance to persuade the electorate of the importance of tackling climate change*, when faced with more immediate, local concerns that are more likely to win votes
- *Local governments that are unrepresentative of and unaccountable* to precisely those sections of their populations that are most vulnerable to climate change: those living in informal settlements and working within the informal economy, whom they regard as "the problem" (Satterthwaite in Bulkeley, 2010)
- *Uncertainty related to the health risks of climate change* (e.g., as concerns changing disease distributions and newly emergent diseases, see Section 10.3)
- *Difficulties related to stakeholder engagement* (see Section 10.2), even for planning and implementing early warning systems in cities

Despite these barriers, on a positive note, there are many "bridge options" that encourage the implementation of adaptation and mitigation strategies. These refer to "no-regret" interventions that generate net social benefits under all future scenarios of climate change (Heltberg et al., 2009). In fact, there are many examples of interventions adopted by different sectors that reduce the risk of climate change to health. Some of them are presented here:

- *Community-based programs designed for disaster risk management*: Interventions in low-income urban settings, small-scale loans, hygiene education, local control and maintenance of water supplies, and neighborhood waste management strategies (Dodman et al., 2010; Obermaier, 2013)
- *Improved flooding-prevention infrastructure* (see Case Studies 3.1, Boulder; 4.3, Jena; 11.B, Dakar; and Chapter 9, Coastal Zones)
- *Revegetation of cities to reduce ambient air temperature and improve air quality*, as presented in Case Study 10.B in Annex 5

The assessment of the health co-benefits of adaptation and/or mitigation strategies can be regarded as a bridge to implementation, but it is important to note that health dis-benefits may also result from climate change adaptation and mitigation strategies. The term "health dis-benefits" refers to interventions adopted by different sectors that increase the adverse impacts of climate change on health. As an example, urban wetlands designed primarily for flood control may promote mosquito breeding (Medlock and Vaux et al., 2011). A full consideration of the health consequences of any adaptation or mitigation strategy is the only way to determine whether a particular adaptation will be beneficial or detrimental to health.

10.7 Knowledge Gaps and Recommended Areas for Further Research

Research and practice that crosses disciplinary boundaries is vital for supporting evidence-based policies and programs to effectively and efficiently address the health risks of climate variability and change in the context of multistressor environments. The recent survey by the WHO regional office for Europe, which has been working to promote health adaptation since the late 1990s, indicated areas where further adaptation research is needed, particularly in developing adaptation and mitigation strategies and action plans; designing and implementing integrated climate, environment, and health surveillance; and sharing best practices (Wolf et al., 2014).

A particular challenge with health adaptation is that local and regional contextual factors are often key determinants of the effectiveness of policies and measures. Therefore, it is important to determine which factors determining the success of particular interventions were broadly applicable and thus can be transferred to other regions and which are unique to a location (such as strong commitment of an individual policy-maker to health adaptation). Stakeholder engagement is crucial to building successful adaptation projects.

Adaptation should focus not just on shorter term outputs to address climate variability, but also on establishing processes to address longer term climate change. To do so, research is needed on projecting the health risks of climate change and on effective approaches to iteratively managing risks that will evolve as the climate continues to change and as development proceeds. The literature remains limited on projections of the magnitude and pattern of possible future health risks of climate change and the efficacy of adaptation in reducing those risks, which means adaptation projects have a limited basis for putting shorter term adaptation into longer term perspectives. Projecting the extent to which alterations in weather patterns may affect future health burdens requires moving beyond simple models based on exposure–response relationships and projected temperature/precipitation change to models that incorporate a range of plausible environmental and socioeconomic futures (Ebi and Rocklov, 2014). Finer temporal and spatial scale models are sorely needed to inform decision-making.

Effectively managing the health risks of climate variability and change requires interventions to explicitly consider risks changing over spatial and temporal scales, with high degrees of uncertainty as to the magnitude, rate, and pattern of changes in a particular location at a particular time. This includes risks from a changing climate as well as from changes in other factors that determine the distribution and incidence of climate-sensitive health outcomes. Here, the issue of cities as incompletely understood complex systems is particularly relevant. In the future, cities are likely to experience climatic risks differently than other settings, and risks may be compounded by migration and other specifically urban factors.

Better understanding the cumulative health effects from multiple climate change–related impacts is also relevant when considering urban adaptation strategies considering the long term.

A critical short-term knowledge gap concerns efficient approaches to capacity-building in the health risks of climate change for the full range of actors: from public health and health care professionals, to the general public, to decision- and policy-makers within the health sector and across ministries. This includes facilitating and developing methods, tools, and guidance documents to support countries as they implement adaptation programs and activities. In its broadest sense, an effective capacity-building initiative would not only develop relevant skills and expertise, but also build the evidence base and enhance collaboration across sectors outside public health.

Another knowledge gap is the need for indicators. Defining indicators for the health risks of climate change is an emerging field (English et al., 2009). An agreed minimum set of indicators, similar to those defined for measuring meteorological and climatological variables, along with means of verification, is needed to help establish baselines and for measuring the degree of success of health adaptation activities. This set could then inform indicators chosen within adaptation projects. Having a common set across projects would help future evaluations.

Research is needed on how to most effectively address adaptation and mitigation jointly to reduce the magnitude of climate change to which health systems will need to adapt later in the century. This is not to divert attention from adaptation, but to note that some activities could beneficially incorporate mitigation at low cost. For example, an organization concerned with adapting health care facilities in urban areas to changes in the magnitude and frequency of extreme weather and climate events could encourage applying for supplementary funding to green the health care sector as well (see Case Study 10.6).

Considering that the urban health system should be prepared for the potentially enhanced disease risks related to climate change, it is relevant to improve research considering current and emerging health threats. Key questions include: How can the populations living in tropical regions be affected by urban heat waves? How can we implement adaptation options for the poorest people in cities?

Some cities currently are experiencing socioenvironmental pressure, like the increase of slums, inequalities, and scarcity of water among others. Increases in research that incorporates climate change pressure on the health system and possible "no-regret" adaptation strategy are necessary. In Case Study 10.1, Box 10.3, and Case Study 10.B, we have examples of adaptation strategies applied in cities. Should they be replicated in other cities around the world?

The increase in urbanization and incomes imply new pressures, including increased demands for food, increased waste, and, if unchecked, increased contamination. Understanding the implications of these issues for urban health systems that are also facing climate change deserves more research.

10.8 Conclusions and Recommendations for Policy

In cities, *health* is associated with social, economic, and environmental determinants (Barata et al., 2011), including climate change. Urban planners usually make decisions in one sphere (e.g., transportation) without complete information on the impacts of these decisions on other spheres (e.g., human health, energy, and natural systems). Therefore, a public health system should advocate for healthy policies, plans, and projects for all urban sectors, including the assessment of the risk of climate change to the health of urban residents.

The potential impact of climate change in the population of different cities varies according to their vulnerability. Therefore, it is relevant to:

- Consistently apply health impact assessment, which can provide a quantitative evaluation of the potential health impacts of scenarios, policies, plans, and projects tailored to the city
- Incorporate climate change projections into city standards, policies, and codes
- Alter existing urban conditions that predispose a population to increased vulnerability during extreme climatic events;
- Apply health impact assessments to proposed adaptation and mitigation strategies intended for reducing climate change health risks in order to adopt:
  - GHG mitigation strategies that result in co-benefits for health of the population and the health system
  - Climate change adaptation strategies that reduce health impacts while reducing GHG emissions
  - "No-regret" adaptation and mitigation strategies that will be beneficial to the population under all future climate change scenarios
- Map intra-urban differences in vulnerability to the impacts of climate change, especially in large cities in the developing world that are highly heterogeneous in terms of equity, infrastructure, housing, population density, and health care
- Implement an early warning systems for extreme events such as storms/floods and heat waves; these can have a positive impact on prevention of morbidity and mortality in urban settings

Preparing for the health consequences of climate-related events necessitates a multisectoral approach. Consequently, it is relevant that:

- Connections between climate change and health in cities are made clear to public health practitioners, city planners, policy makers, and the general public
- Urban practitioners take immediate responsibility for integrating climate change projections in all areas of urban planning
- Adaptation strategies focus on activities that eliminate health disparities, improve neighborhood conditions, and protect those who will be most impacted by climate change
- Successful methodologies for climate change adaptation strategies designed and implemented in cities count on the

collaboration of researchers and consultants in urban management so that they can be tailored to other cities

- International networks be established, maintained, and supported to provide forums for data exchange, disease surveillance, intervention evaluation, and ongoing research into the health impacts of climate change in urban areas

Annex 10.1 Stakeholder Engagement

Stakeholder engagement is critical for achieving success in managing health risk due to climate change in cities. In Figure 10.3, we present an integrated view of institutions and sectors that are relevant in managing those risks in order to protect urban populations.

We aimed to develop a chapter that is both scientifically robust and helpful to authorities and professionals involved in managing health climate risk in cities. To better respond to this challenge, we decided to invite as reviewers for our chapter experts in climate change and health from the WHO, the National Resource Defense Council, and the Health Research Institution, as well as outstanding city health managers and other city health advisors. The participation of stakeholders as chapter reviewers was relevant for the content and shape of this chapter. Protecting the health of the world's urban population requires the involvement of stakeholders specialized in diverse disciplines such as health, planning, engineering, meteorology, ecology, epidemiology, and others. Finally, we hope stakeholders, city governments, the business and academic communities, consultants, or citizens interested in managing health risks due to climate change in cities will find this chapter useful.

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References

Admassie, A., Adenew, B., and Tadege, A. (2008). Perceptions of stakeholders on climate change and adaptation strategies in Ethiopia. *IFPRI Research Brief* **15**(6).

Aldrich, D. P. (2012). *Building Resilience: Social Capital in Post-Disaster Recovery*. University of Chicago Press.

Anderson, G. B., and Bell, M. L. (2012). Lights out: Impact of the August 2003 power outage on mortality in New York, NY. *Epidemiology* **23**(2), 189.

Barata, M., Ligeti, E., de Simone, G., Dickinson, T., Jack, D., Penney, J., Rahman, M., and Zimmerman, R. (2011). Climate change and human health in cities. In Rosenzweig, C., Solecki, S. A. Hammer and Mehrotra, S. (eds.), *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network* (183–217). Cambridge University Press.

Basu, R., Malig, B., and Ostro, B. (2010). High ambient temperature and the risk of preterm delivery. *American Journal of Epidemiology* **172**(10), 1108–1117. Accessed December 9, 2015: http://doi.org/10.1093/aje/kwq170

Batty, M. (2008). *Cities as complex systems: Scaling, interactions, networks, dynamics and urban morphologies*. In *The Encyclopedia of Complexity & System Science*. Springer.

Beatty, M. E., Phelps, S., Rohner, C., and Weisfuse, I. (2006). Blackout of 2003: Public health effects and emergency response. *Public Health Reports* **121**(1), 36–44.

Berry, H. L., Bowen, K., and Kjellstrom, T. (2010). Climate change and mental health: A causal pathways framework. *International Journal of Public Health* **55**(2), 123–132.

Bhatt, S., Gething, P. W., Brady, O. J., Messina, J. P., Farlow, A. W., Moyes, C. L., Drake, J. M., Brownstein, J. S., Hoen, A. G., Sankoh, O., Myers, M. F., George, D. B., Jaenisch, T., Wint, G. R. W., Simmons, C. P., Scott, T. W., Farrar, J. J., and Hay, S. I. (2013). The global distribution and burden of dengue. *Nature* **496**(7446), 504–507

Bierbaum, R., Smith, J. B., Lee, A., Blair, M., Carter, L., Chapin III, F. F., Fleming, P., Rufio, S., Stults, M., McNeely, S., Wasley, E., and Verduzco, L. (2013). A comprehensive review of climate adaptation in the United States: More than before, but less than needed. *Mitigation and Adaptation Strategies for Global Change* **18**(3), 361–406.

Bouzid, M., Hooper, L., and Hunter, P. R. (2013). The effectiveness of public health interventions to reduce the health impact of climate change: A systematic review of systematic reviews. *PLoS One* **8**(4). Accessed November 8, 2014: http://www.readcube.com/articles/10.1371/journal.pone.0062041

Bowen, K. J., Friel, S., Ebi, K., Butler, C. D., Miller, F., and McMichael, A. J. (2012). Governing for a healthy population: Towards an understanding of how decision-making will determine our global health in a changing climate. *International Journal of Environmental Research and Public Health* **9**(1), 55–72.

Bulkeley, H. (2010). Cities and the governing of climate change. *Annual Review of Environmental Resources* **35**, 229–253.

Cakmak, S., Dales, R. E., Burnett, R. T., Judek, S., Coates, F., and Brook, J. R. (2002). Effect of airborne allergens on emergency visits by children for conjunctivitis and rhinitis. *Lancet* **359**(9310), 947–948. Accessed May 23, 2014: http://doi.org/10.1016/S0140-6736(02)08045-5

CAP. (2007). *Cities Preparing for Climate Change A Study of Six Urban Regions*. Clean Air Partnership.

Carlsson-Kanyama, A., Carlsen, H., and Dreborg, K.H (2013). Barriers in municipal climate change adaptation: Results from case studies using backcasting. *Futures* **49**, 9–21.

Carmin, J., Anguelovski, I., and Roberts, D. (2012). Urban climate adaptation in the Global South: Planning in an emerging policy domain. *Journal of Planning, Education, and Research* **32**, 18–32.

Carmin, J., Nadkarni, N., and Rhie, C. (2012). *Progress and Challenges in Urban Climate Adaptation Planning: Results of a Global Survey*. MIT Press.

Castán Broto, V., and Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. *Global Environmental Change* **23**, 92–102.

CCSP. (2008). *Weather and climate extremes in a changing climate: Regions of focus: North America, Hawaii, Caribbean and U.S. Pacific Islands*. In Karl, T. R., Meehl, G. A., Miller, C. D., Hassol, S. J., Waple, A. M., and Murray, W. L. (eds.), *Synthesis and Assessment Product 3.3, Report by the United States Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research*. Department of Commerce, NOAA's National Climatic Data Center.

Centro Regional De Información Sobre Desastres (CRID). (2009). *Casos de estudio*. Accessed June 3, 2014: http://www.crid.or.cr/CD/CD_hospitales_Seguros/casos-estudio.html

Chamlee-Wright, E., and Storr, V. H. (2011). Social capital as collective narratives and post-disaster community recovery. *Sociology Review* **59**, 266–282. doi:10.1111/j.1467-954X.2011.02008.x

Cheng, D. S., Campbell, M., Li, Q., Li, G., Auld, H., Day, H., Pengelly, D., Gingrich, S., Klaassen, J., MacIver, D., Comer, N., Mao, Y., Thompson, W., and Lin, H. (2010). Differential and combined impacts of extreme temperatures and air pollution on human mortality in south-central Canada. Part II: Future estimates. *Air Quality and Atmospheric Health* 2008(**1**), 223–235.

Chung, W. M., Buseman, C. M., Joyner, S. N., Hughes, S. M., Fomby, T. B., Luby, J. P., and Haley, R. W. (2013). The 2012 West Nile encephalitis epidemic in Dallas, Texas. *JAMA* **310**(3), 297–307.

City of Toronto. (2014). Resilient city: Preparing for a changing climate. Accessed January 14, 2015: http://www.toronto.ca/legdocs/mmis/2014/pe/bgrd/backgroundfile-70623.pdf

Colón-González, F. J., Fezzi, C., Lake, I. R., and Hunter, P. R. (2013). The effects of weather and climate change on dengue. *PLoS Neglected Tropical Diseases* **7**(11), e2503. doi:10.1371/journal.pntd.0002503

Confalonieri, U., Barata, M. M. L., and Marinho, D. (2014). Vulnerabilidade Climática no Brasil. In Chang, M. et al. (eds.), *Metodologias de Estudos de Vulnerabilidade à Mudança do Clima*. Coletâneas Mudanças Globais, Ed. Interciências. Volume 5. IVIG/COPPE-UFRJ.

Curriero, F. C., Patz, J. A., Rose, J. B., and Lele, S. (2001). The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. *American Journal of Public Health* **91**(8), 1194–1199.

De Sario, M., Katsouyanni, K., and Michelozzi, P. (2013). Climate change, extreme weather events, air pollution and respiratory health in Europe. *European Respiratory Journal* **42**, 826–843.

Delfino, R. J. (2002). Epidemiologic evidence for asthma and exposure to air toxics: Linkages between occupational, indoor, and community air pollution research. *Environmental Health Perspectives* **110(**Suppl 4), 573–589.

Dennekamp, M., and Carey, M. (2010). Air quality and chronic disease: Why action on climate change is also good for health. *New South Wales Public Health Bulletin* **21**(5–6), 115–121. Accessed December 1, 2014: http://doi.org/10.1071/NB10026

Dodman, D., Mitlin, D., and. Rayos, C. J. (2010). Victims to victors, disasters to opportunities: Community driven response to climate change in the Philippines. *International Development Planning Review* **32**(1), 1–26.

Ebi, K. (2011). Climate change and health risks: Assessing and responding to them through "adaptive management." *Health Affairs (Millwood)* **30**(5), 924–930.

Ebi, K. L., Grambsch, A. E., Sussman, F. G., and Wilbanks, T. J. (2008). Effects of global change on human health. In *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*. UNT Digital Library. Accessed November 30, 2014: http://digital.library.unt.edu/ark:/67531/metadc12033/citation/

Ebi, K. L., and McGregor, G. (2008). Climate change, tropospheric ozone and particulate matter, and health impacts. *Environmental Health Perspectives* **116**(11), 1449–1455. Accessed June 8, 2015: http://doi.org/10.1289/ehp.11463

Ebi, K. L., and Rocklov, J. (2014). Climate change and health modelling: Horses for courses. *Global Health Action* 7, 24154. Accessed September 28, 2015: http://dx.doi.org/10.3402/gha.v7.24154

European Centre for Disease Prevention and Control (ECDC). (2011). *Climate Change and Communicable Diseases in the EU Member States: A Handbook for National Vulnerability, Impact and Adaptation Assessments*. ECDC.

English, P. B., Sinclair, A. H., Ross, Z., Anderson, H., Boothe, V., Davis, C., Ebi, K., Kagey, B., Malecki, K., Schultz, R., and Simms, E. (2009). Environmental health indicators of climate change for the United States: Findings from the State Environmental Health Indicator Collaborative. *Environmental Health Perspective* **117**, 1673–1681.

FAO. (2011). Global food losses and food waste. Accessed December 1, 2014: http://www.fao.org/fileadmin/user_upload/sustainability/pdf/Global_Food_Losses_and_Food_Waste.pdf

FAO. (2014). *Growing Greener Cities in Latin America and the Caribbean*. A FAO Report on Urban and Peri-urban Agriculture in the Region.

Fleck, F. (2014). Bringing air pollution into the climate change equation. *Bulletin of the World Health Organization* **92**, 553–554.

Freitas, C. M., Silva, M. E., and Osorio-de-Castro, C. G. S. (2014). A redução dos riscos de desastres naturais como desafio para a saúde coletiva. *Ciência e Saúde Coletiva (Impresso)* V. **19**, 3628–3628

Friel, S., Dangour, A. D., Garnett, T., Lock, K., Chalabi, Z., Roberts, I., and McMichael, A. J. (2009). Health and Climate Change 4 Public health benefits of strategies to reduce greenhouse-gas emissions: Food and agriculture. *Nutrition*. doi:10.1016/S0140-6736(09)61753-0

Frumkin, H., Hess, J., Luber, G., Malilay, J., and McGeehin, M. (2008). Climate change: The public health response. *American Journal of Public Health* **98**(3), 435–445.

Frumkin, H., McMichael, A. J., and Hess, J. J. (2008). Climate change and the health of the public. *American Journal of Preventive Medicine* **35**(5), 401–402. Accessed August 26, 2014: http://doi.org/10.1016/j.amepre.2008.08.031

Fussell, E., and Lowe, S. R. (2014). The impact of housing displacement on the mental health of low-income parents after Hurricane Katrina. *Social Science and Medicine* **113**, 137–144. doi:10.1016/j.socscimed.2014.05.025

Ghebreyesus, T. A., Tadesse, Z., Jima, D., Bekele, E., Mihretie, A., Yihdego, Y. Y., Dinku, T., Connor, S. J., and Rogers, D. P. (2009). Using climate information in the health sector. Field Actions Science Reports, Vol. 2. Accessed July 19, 2014: http://factsreports.revues.org/178

Greenwood, M. (2007). Stakeholder engagement: Beyond the myth of corporate responsibility. *Journal of Business Ethics* **74**, 315–327.

Haines, A., McMichael, A. J., Smith, K. R., Roberts, I., Woodcock, J., Markandya, A., and Wilkinson, P. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: Overview and implications for policy makers. *The Lancet* **374**(9707), 2104–2114. doi:10.1016/S0140-6736(09)61759-1.

Harlan, S. L., and Ruddell, D. M. (2011). Climate change and health in cities: Impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinions in Environmental Sustainability* **3**, 126–134.

Health Canada (2011). *Adapting to Extreme Heat Events: Guidelines of Assessing Health Vulnerability*. Health Canada. Accessed November 18, 2015: www.healthcanada.gc.ca

Heltberg, R., Siegel, P. B., and Jorgensen, S. L. (2009). Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change* **19**, 89–99.

Hess, J. J., McDowell, J. Z., and Luber, G. (2012). Integrating climate change adaptation into public health practice: Using adaptive management to increase adaptive capacity and build resilience. *Environmental Health Perspectives* **120**, 171–179.

Hohnen, P. (2007). *Corporate Social Responsibility: An Implementation Guide for Business*. International Institute for Sustainable Development, Canada. Accessed January 9, 2016: http://www.iisd.org/pdf/2007/csr_guide.pdf

Humphreys, G. (2014). Reframing climate change as a health issue. *Bulletin of the World Health Organization* **92**, 551–552.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate Change 2007: 2.3.2 Stakeholder involvement in Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry, M. L., Canziani, O. F., Palutikof, J. P., van, P. J.der Linden and Hanson, C. E. (eds.). Cambridge University Press.

Intergovernmental Panel on Climate Change (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*, Field, C. B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi, K. L., Mastrandrea, M. D., Mach, K. J.,Plattner, G. -K. Allen, S. K., Tignor, M., and Midgley, P. M. (eds.). Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability, Summaries, Frequently Asked Questions, and Cross-Chapter Boxes. A Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Field, C.B., Barros, V. R., Dokken, D. J., Mach, J. K., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.). World Meteorological Organization (in Arabic, Chinese, English, French, Russian, and Spanish). Accessed January 21, 2016: http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-IntegrationBrochure_FINAL.pdf

Jaakkola, J. J. K., Hwang, B. F., and Jaakkola, N. (2005). Home dampness and molds, parental atopy, and asthma in childhood: A six-year population-based cohort study. *Environmental Health Perspectives* **113**(3), 357–361.

Jacob, D. J., and Winner, D. A. (2009). Effect of climate change on air quality. *Atmospheric Environment* **43**(1), 51–63. Accessed March 2, 2016: http://doi.org/10.1016/j.atmosenv.2008.09.051

Jacobson, L. da S. V., Hacon, S. de S., de, H. A., Castro, Ignotti, E., Artaxo, P., Saldiva, P. H. N., and de Leon, A. C. M. P. (2014). Acute effects of particulate matter and black carbon from seasonal fires on peak expiratory flow of schoolchildren in the Brazilian Amazon. *PloS One* **9** (8), e104177. Accessed February 9, 2015: http://doi.org/10.1371/journal.pone.0104177

Kampa, M., and Castanas, E. (2008). Human health effects of air pollution. *Environmental Pollution (Barking, Essex: 1987)* **151**(2), 362–367. Accessed November 30, 2014: http://doi.org/10.1016/j.envpol.2007.06.012

Kates, R. W., Travis, W. R., et al. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences* **109**(19), 7156–7161.

Kelly-Hope, L. A., Hemingway, J., and McKenzie, F. E. (2009). Environmental factors associated with the malaria vectors *Anopheles gambiae* and *Anopheles funestus* in Kenya. *Malaria Journal* **8**(268), 1–8.

KEMA, Inc. (2012). *A guide to developing a climate action plan using regionally integrated climate action plan suite*. City/County Association of Governments of San Mateo County, California, USA. Accessed October 9, 2014: http://www.smcenergywatch.com/sites/default/files/RICAPS_Users%20Guide_v1.pdf

Kinney, P. L. (2008). Climate Change, Air Quality, and Human Health. *American Journal of Preventive Medicine* **35**(5), 459–467. Accessed October 18, 2014: http://doi.org/10.1016/j.amepre.2008.08.025

Kinney, P. L., Schwartz, J., Pascal, M., Petkova, E., Le Tertre, A., Medina, S., and Vautard, R. Winter seasons mortality: Will climate warming bring benefits? *Environmental Research Letters* 10(2015), 064016. doi:10.1088/1748-9326/10/6/064016.

Knowlton, K., Kulkarni, S. P., Azhar, G. S., Mavalankar, D., Jaiswal, A., Connolly, M.,Nori, A. -Sarma, Rajiva, A., Dutta, P., Deol, B., Sanchez, L., Khosla, R., Webster, P. J., Toma, V. E., Sheffield, P., Hess, J. J., the Ahmedabad Heat and Climate Study Group (2014). Development and Implementation of South Asia's First Heat-Health Action Plan in Ahmedabad (Gujarat, India). *International Journal of Environmental Research and Public Health* **11**, 3473–3492. doi:10.3390/ijerph110403473

Knowlton, K., Rotkin, M. Ellman, King, G., Margolis, H. G., Smith, D., Solomon, G.,English, P. (2009). The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. *Environmental Health Perspectives* **117**(1), 61–67. Accessed February 9, 2015: http://doi.org/10.1289/ehp.11594

Lane, K., Charles -Guzman, K., Wheeler, K., Abid, Z., Graber, N., and Matte, T. (2013). Health effects of coastal storms and flooding in urban areas: A review and vulnerability assessment. *Journal of Environmental and Public Health*. Article ID 913064.

Lesnikowski, A. C., Ford, J. D., Berrang-Ford, L., Barrera, M., Berrz, P., Henderson, J., and Hezmann, S. J. (2013). National-level factors affecting planned, public adaptation to health impacts of climate change. *Global Environmental Change* **23**(5), 1153–1163

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., and Andrews, K. G. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. *The Lancet* **380**(9859), 2224–2260. Accessed November 30, 2014: http://doi.org/10.1016/S0140-6736(12)61766-8

Lin, S., Fletcher, B. A., Luo, M., Chinery, R., and Hwang, S. -A. (2011). Health impact in New York City during the Northeastern blackout of 2003. *Public Health Reports* (Washington, D.C.: 1974) **126**(3), 384–393.

Lin, S., Luo, M., Walker, R. J., Liu, X.,Hwang, S. -A., and Chinery, R. (2009). Extreme high temperatures and hospital admissions for respiratory and cardiovascular diseases. Epidemiology **20**(5), 738–746. Accessed October 9, 2014: http://doi.org/10.1097/EDE.0b013e3181ad5522

Littell, J. (2010). Engaging stakeholders in climate change adaptation. CAKE. Accessed October 18, 2014: http://www.cakex.org/virtual-library/engaging-stakeholders-climate-change-adaptation

Lo, E., and Levetin, E. (2007). Influence of meteorological conditions on early spring pollen in the Tulsa atmosphere from 1987–2006. *Journal of Allergy and Clinical Immunology* **119** (1),S101. Accessed June 15, 2015: http://doi.org/10.1016/j.jaci.2006.11.612

McMichael, A. J. (2001). Global environmental change as "risk factor": Can epidemiology cope? *American Journal of Public Health* **91**(8), 1172–1174.

McMichael, A. J., Wilkinson, P., Kovats, R. S., Pattenden, S., Hajat, S., Armstrong, B., and Nikiforov, B. (2008). International study of temperature, heat and urban mortality: The "ISOTHURM" project. *International Journal of Epidemiology* **37**(5), 1121–1131. Accessed May 14, 2014: http://doi.org/10.1093/ije/dyn086

Medlock, J. M., and Vaux, A. G. C. (2011). Assessing the possible implications of wetland expansion and management on mosquitoes in Britain. *European Mosquito Bulletin* 29, 38–65.

Minero, F. J. G., Candau, P., Morales, J., and Tomas, C. (1998). Forecasting olive crop production based on ten consecutive years of monitoring airborne pollen in Andalusia (southern Spain). *Agriculture Ecosystems & Environment* **69**(3), 201–215. http://doi.org/10.1016/S0167-8809(98)00105-4

Morrow, G., and Bowen, K. (2014). Accounting for health in climate change policies: A case study in Fiji. *Global Health Action* 7, 23550. Accessed June 25, 2015: http://dx.doi.org/10.3402/gha.v7.23550

Moser, S. C., and Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences* **107**(51), 22026–22031.

Mueller, S. F., and Mallard, J. W. (2011). Contributions of natural emissions to ozone and PM2.5 as simulated by the Community Multiscale Air Quality (CMAQ) model. *Environmental Science & Technology* **45**(11), 4817–4823. Accessed December 20, 2014: http://doi.org/10.1021/es103645 m

Murray, C. J. L., Rosenfeld, L. C., Lim, S. S., Andrews, K. G., Foreman, K. J., Haring, D., Fullman, N., Naghavi, M., Lozano, R., and Lopez, A. D. (2012). Global malaria mortality between 1980 and 2010: A systematic analysis. *The Lancet* **379**, 413–431

Mustelin, J., Kuruppu, N., Kramer, A. M., Daron, J., Bruin, K., and Noriega, A. G. (2013). Climate adaptation research for the next generation. *Climate and Development* **5**(3), 189–193.

National Research Council (NRC). (2012). *Climate and Social Stress: Implications for Security Analysis. Committee on Assessing the Impacts of Climate Change on Social and Political Stresses*, J. D. Steinbruner, P. C. Stern and J. L. Husbands (eds.), Board on Environmental Change and Society, Division of Behavioral and Social Sciences and Education (253). The National Academies Press.

Obermaier, M. (2013). *City-Level Climate Change Adaptation Strategies: The Case of Quito, Ecuador*. ELLA Case Study Brief. Practical Action Peru, Lima.

Ogden, N. H., St-Onge, L., Barker, I. K., Brazeau, S.,Bigras, M. -Poulin, Charron, D. F., and Thompson, R. A. (2008). Risk maps for range expansion of the Lyme disease vector, Ixodes scapularis, in Canada now and with climate change. *International Journal of Health Geographics* **7**, 24. Accessed January 23, 2016: http://doi.org/10.1186/1476-072X-7-24

Ogden, N. H., Bouchard, C., Kurtenbach, K., Margos, G., Lindsay, L. R., Trudel, L., and Milord, F. (2010). Active and passive surveillance and phylogenetic analysis of Borrelia burgdorferi elucidate the process of Lyme disease risk emergence in Canada. *Environmental Health Perspectives* **118**(7), 909–914. Accessed April 28, 2014: http://doi .org/10.1289/ehp.0901766

O'Haire, C., McPheeters, M., Nakamoto, E. K., LaBrant, L., Most, C., Lee, K., Graham, E., Cottrell, E., and Guise, J-M. (2011). Methods for engaging stakeholders to identify and prioritize future research needs. Methods Future Research Needs Report No. 4. AHRQ Publication No. 11-EHC044-EF. Agency for Healthcare Research and Quality. June 2011. Accessed January 27, 2016: www.effectivehealthcare.ahrq .gov/reports/final.cfm.

OMS. (2012). *Atlas of Health and Climate*. World Health Organization.

Omumbo, J., Lyon, B., Waweru, S., Connor, S., and Thomson, M. (2011). Raised temperatures over the Kericho tea estates: Revisiting the climate in the East African highlands malaria debate. *Malaria Journal* **10**(12).

O'Neill, M. S., Zanobetti, A., and Schwartz, J. (2005). Disparities by race in heat-related mortality in four U.S. cities: The role of air conditioning prevalence. *Journal of Urban Health: Bulletin of the New York Academy of Medicine* **82**(2), 191–197. Accessed December 11, 2014: http://doi.org/10.1093/jurban/jti043

Pan American Health Organization (PAHO). (2014). Plan of action for the prevention of obesity in children and adolescents. Pan American Health Organization and World Bank. Accessed August 10, 2015: http://www.paho.org/hq/index.php?option=com_docman&task=doc_view&Itemid=270&gid=28890&lang=en

Pan American Health Organization (PAHO). (2009). What is the Hospital Safety Index?. Accessed July 1, 2014: http://www1.paho.org/english/dd/ped/SafeHospitalsChecklist.htm

Panic, M., and Ford, J. D. (2013). A review of national-level adaptation planning with regards to the risks posed by climate change on infectious diseases in 14 OECD nations. *International Journal of Environmental Research and Public Health* **10**, 7083–7109.

Paterson, J. A., and Ford, J. D., et al. (2012). Adaptation to climate change in the Ontario public health sector. *BMC Public Health* **12**(1), 452.

Patz, J. A., Frumkin, H., Holloway, T., Vimont, D. J., and Haines, A. (2014). Climate change challenges and opportunities for global health. *JAMA* **312**(15), 1565–1580. doi:10.1001/jama.2014.13186

Patz, J. A., Vavrus, S. J., Uejio, C. K., and McLellan, S. L. (2008). Climate change and waterborne disease risk in the Great Lakes region of the U.S. *American Journal of Preventive Medicine* **35**(5), 451–458. Accessed April 11, 2014: http://doi.org/10.1016/j.amepre.2008.08.026

Pereira, C. A. R., and Barata, M. M. L. (2014a). Organização dos serviços urbanos de saúde frente à mudança do clima e ao risco de desastres na América Latina. *Saude em Debate* **38**, 624–634.

Pereira, C. A. R., Barata, M. M. L., Hoelz, M. P. C., Medeiros, V. N. L. O., Marincola, F. C. V., Neto, C. C., Marinho, D. P., Oliveira, T. V. S., Trigo, A. M., and Medeiros, K. (2014b). Economic evaluation of cases of dengue fever attributed to the disaster of 2011 in Nova Friburgo, Brasil. *Ciênc. saúde Coletiva* **19**(9), 3693–3704.

Pereira, C. A. R., Barata, M. M. L., and Trigo, A. M. (2014c). Social cost of leptospirosis cases attributed to the 2011 disaster striking Nova Friburgo, Brazil. *International Journal of Environmental Research and Public Health* **11**, 4140–4157.

Pfister, G. G., Wiedinmyer, C., and Emmons, L. K. (2008). Impacts of the fall 2007 California wildfires on surface ozone: Integrating local observations with global model simulations. *Geophysical Research Letters* **35**(19), L19814. Accessed October 17, 2014: http://doi.org/10.1029/2008GL034747

Prain, G., and Dubbeling, M. (2010). *Case Studies of the Cities of Accra, Nairobi, Lima, and Bangalore Undertaken.* RUAF Foundation.

Prain, G., and Dubbeling, M. (2010). Case Studies of the Cities of Accra, Nairobi, Lima, and Bangalore Undertaken. RUAF Foundation.

Pope, C. A., 3rd, Burnett., R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., and Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association* **287**(9), 1132–1141.

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., Lobell, D. B., and Travasso, M. I. (2014). Food security and food production systems. In Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* (485–533). Cambridge University Press.

Reid, C. E., O'Neill, M. S., Gronlund, C. J., Brines, S.J, Brown, D.G, Diey-Roux, A.V, and Schwarty, J. (2009). Mapping community determinants of heat vulnerability. *Environmental Health Perspectives* **117**, 1730–1736.

Reiss, N. M., and Kostic, S. R. (1976). Pollen season severity and meteorologic parameters in central New Jersey. *Journal of Allergy and Clinical Immunology* **57**(6), 609–614.

Rekow, L. (2015). Fighting insecurity: Experiments in urban agriculture in the favelas of Rio de Janeiro. *Field Actions Science Reports*, 8.

Revi, A., Satterthwaite, D. E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B. R., Pelling, M., Roberts, D. C., and Solecki, W. (2014). Urban areas. In Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (535–612). Cambridge University Press.

Rittmaster, R., Adamowicz, W. L., Amiro, B., and Pelletier, R. T. (2006). Economic analysis of health effects from forest fires. *Canadian Journal of Forest Research* **36**(4), 868–877. Accessed September 9, 2014: http://doi.org/10.1139/X05-293

Romero-Lankao, P., Hughes, S.,Rosas, A. -Huerta, Borquez, R., and Gnatz, D. M. (2013a). Institutional capacity for climate change responses: An examination of construction and pathways in Mexico City and Santiago. *Environmental Planning and Government Policy* **31**, 785–805.

Romero-Lankao, P., Qin, H., and Borbor-Cordova, M. (2013). Exploration of health risks related to air pollution and temperature in three Latin American cities. *Social Science and Medicine* **83**, 110–118.

Romero-Lankao, P., Qin, H., and Dickinson, K. (2012). Urban vulnerability to temperature-related hazards: A meta-analysis and meta-knowledge approach. *Global Environmental Change* **12**, 670–683.

Rose, J. B., Epstein, P. R., Lipp, E. K., Sherman, B. H., Bernard, S. M., and Patz, J. A. (2001). Climate variability and change in the United States: Potential impacts on water- and foodborne diseases caused by microbiologic agents. *Environmental Health Perspectives* **109**(Suppl 2), 211–221.

Rosenzweig, C., Solecki, W., Hammer, S. A., and Mehrotra, S. (2010). Cities lead the way in climate-change action. *Nature* **467**, 909–911.

Rosenzweig, C., and Solecki, W. (2010). Introduction to climate change adaptation in New York City: Building a risk management response. *Annals of the New York Academy of Sciences* **1196**(1), 13–17.

Rosenzweig, C., Solecki, W. D., and Slosberg, R. B. (2006). *Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces*. New York City Regional Heat Island Initiative, Final Report 06–06. New York State Energy Research and Development Authority.

Ruckart, P. Z., Orr, M. F., Lanier, K., and Koehler, A. (2008). Hazardous substances releases associated with Hurricanes Katrina and Rita in industrial settings, Louisiana and Texas. *Journal of Hazardous Materials* **159**(1), 53–57.

Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., De, G.Grandis, Groce, N., Hallal, P. C., Hamilton, I., Howden-Chapman, P., Lai, K-M., Lim, C., Martins, J., Osrin, D., Ridley, I., Scott, I., Taylor, M., Wilkinson, P., and Wilson, J. (2012). Shaping cities for health: Complexity and the planning of urban environments in the 21st century. *The Lancet* **379**, 2079–2108.

Samet, J.M, Zeger, S.L., Dominici, F., Curriero, F., Coursac, I., Dockery, D. W., Schwarty, J., and Yanobetti, A. (2000). The National Morbidity, Mortality, and Air Pollution Study Part II: Morbidity and mortality from air pollution in the United States. Accessed August 6, 2015: http://www.cabq.gov/airquality/documents/pdf/samet2.pdf

Sastry, N., and Gregory, J. (2013). The effect of Hurricane Katrina on the prevalence of health impairments and disability among adults in New Orleans: Differences by age, race, and sex. *Social Science and Medicine* **80**, 121–129.

Satterthwaite, D., Huq, S., Reid, H., Pelling, M., and Romero-Lankao, P. (2008). *Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-Income Nations*. *IIED*.

Schmeer, K. (1999). *Guidelines for Conducting a Stakeholder Analysis*. Partnerships for Health Reform, Abt Associates Inc for the World Health Organization.

Schwartz, J. (1994). Air pollution and daily mortality: A review and meta-analysis. *Environmental Research* **4**, 36–52

Semenza, J. C., Herbst, S., Rechenburg, A., Suk, J. E., Höser, C., Schreiber, C., and Kistemann, T. (2012). Climate change impact assessment of food- and waterborne diseases. *Critical Reviews in Environmental Science and Technology* **42**(8), 857–890. Accessed December 11, 2014: http://doi.org/10.1080/10643389.2010.534706

Semenza, J. C., Sudre, B., Oni, T., Suk, J. E., and Giesecke, J. (2013). Linking environmental drivers to infectious diseases: The European Environment and Epidemiology Network. *PLoS Neglected Tropical Diseases* **7** (7), e2323.

Sena, A. L., Barcellos, C. L., Freitas, C., and Corvalan, C. (2014). Managing the health impacts of drought in Brazil. *International Journal of Environmental Research and Public Health* **11**, 10737–10751.

Sheffield, P. E., Knowlton, K., Carr, J. L., and Kinney, P. L. (2011). Modeling of regional climate change effects on ground-level ozone and childhood asthma. *American Journal of Preventive Medicine* **41**(3), 251–257; quiz A3. Accessed February 27, 2016: http://doi.org/10.1016/j.amepre.2011.04.017

Silva, C. B. P., Saldiva, P. H. N., Lourenço, L. F. A., Silva, F. R., and Miraglia, S. G. K. (2012). Evaluation of the air quality benefits of the subway system in São Paulo, Brazil. *Journal of Environmental Management* **101**, 191–196

Smith, K. R., Jerrett, M., Anderson, H. R., Burnett, R. T., Stone, V., Derwent, R., and Thurston, G. (2009). Health and Climate Change 5 Public health benefits of strategies to reduce greenhouse-gas emissions: Health implications of short-lived greenhouse pollutants. *The Lancet* **374**(9707), 2091–2103. doi:10.1016/S0140-6736(09)61716-5

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., Olwoch, J. M., Revich, B., and Sauerborn, R. (2014). Human health: Impacts, adaptation, and co-benefits. In Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (709–754). Cambridge University Press.

Solecki, W., Patrick, L., Brady, M., Grady, K., and Maroko, A. (2010). Climate protection levels: Incorporating climate change into design and performance standards. New York City Panel on Climate Change. *Annals of the New York Academy of Sciences* **1196**(1), 293–352.

Stott, P., and Walton, P. (2013). Attribution of climate-related events: Understanding stakeholder needs. *Weather* **68**(10), 274–279.

Sudhinaraset, M., Ingram, M., Lofthouse, H. K., and Montagu, D. (2013). What is the role of informal healthcare providers in developing countries? A systematic review. *PLoS ONE* **8**, e54978.

Toronto Public Health (TPH). (2011). Protecting vulnerable people from the health impacts of extreme heat. Accessed August 13, 2015: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2011.HL6.3

Toronto Public Health (TPH). (2014a). Path to healthier air. Accessed November 14, 2015: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2014.HL30.1

Toronto Public Health (TPH). (2014b). Active city: Designing for health. Accessed November 9, 2015: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2014.HL31.1

Tsai, D. -H., Wang, J. -L., Wang, C. -H., and Chan, C. -C. (2008). A study of ground-level ozone pollution, ozone precursors and subtropical meteorological conditions in central Taiwan. *Journal of Environmental Monitoring: JEM* **10**(1), 109–118. Accessed September 7, 2014: http://doi.org/10.1039/b714479b

U.S. Energy Information Administration. (2007). Energy characteristics and energy consumed in large hospital buildings in the United States in 2007. Accessed June 12, 2014: http://www.eia.gov/consumption/commercial/reports/2007/large-hospital.cfm

U.S. Environmental Protection Agency (EPA) National Center for Environmental Assessment, I. O. (2008). A review of the impact of climate variability and change on aeroallergens and their associated effects (final report). Accessed July 23, 2015: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190306

U.S. Global Change Research Program. (2014). National Climate Assessment. Accessed September 22, 2015: http://nca2014.globalchange.gov/node/1961

USGCRP. (2008). *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems (SAP 4.6)*. Washington, D.C.: U.S. Environmental Protection Agency.

Vardoulakis, S., Dear, K., Hajat, S., Heaviside, C., Eggen, B., and McMichael, A. J. (2014). Comparative assessment of the effects of climate change on heat and cold related mortality in cities of United Kingdom and Australia. *Environmental Health Perspectives* **122**(12), 1285–1292.

Villeneuve, P. J., Doiron, M. -S., Stieb, D., Dales, R., Burnett, R. T., and Dugandzic, R. (2006). Is outdoor air pollution associated with physician visits for allergic rhinitis among the elderly in Toronto, Canada? *Allergy* **61**(6), 750–758. Accessed March 16, 2014: http://doi.org/10.1111/j.1398-9995.2006.01070.x

Walters, V., and Gaillard, J. C. (2014). Disaster risk at the margins: Homelessness, vulnerability and hazards. *Habitat International* **44**, 211–219.

Weible, C. M. (2007). An advocacy coalition framework approach to stakeholder analysis: Understanding the political context of California Marine Protected Area Policy. *Journal of Public Administration Research and Theory* **17**, 95–117.

Weisler, R. H., Barbee, J. G., and Townsend, M. H. (2006). Mental health and recovery in the Gulf Coast after Hurricanes Katrina and Rita. *JAMA* **296**(5), 585–588.

Westerling, A. L. (2006). Warming and earlier spring increase western U.S. forest wildfire activity. *Science* **313**(5789), 940–943. Accessed January 6, 2015: http://doi.org/10.1126/science.1128834

Wheeler, K., Lane, K., Walters, S., and Matte, T. (2013). Heat illness and deaths – New York City, 2000–2011. (Cover story). *MMWR: Morbidity & Mortality Weekly Report* **62**(31), 617–621.

White-Newsome, J. L., McCormick, A., Sampson, N., Buxton, M. A., O'Neill, M. S., Gronlund, C. J., Catalano, L., Conlon, K., and Parker, E. A. (2014). Strategies to reduce the harmful effects of extreme heat events: A four-city study. *International Journal of Environmental Research and Public Health* **11**, 1960–1988.

Wolf, T., Sanchez Martinez, G., Cheong, H. -K., Williams, E., and Menne, B. (2014). Protecting health from climate change in the WHO European region. *International Journal of Environmental Research and Public Health* **11**, 6265–6280.

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Y., Chowdhury, Y., Cohen, A., Franco, O.H, Haines, A., Hickman, R., Lindsay, G., Mittal, I., Mohan, D., Tiwari, G., Woodward, A., and Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: Urban land transport. *The Lancet* **374**(9705), 1930–1943. doi:10.1016/S0140-736(09)61714-1.

World Bank. (2016). Gini index (World Bank estimate), Development Research Group. Accessed March 16, 2017: http://data.worldbank.org/indicator/SI.POV.GINI

World Health Organization (WHO). (1946). *Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference*, New York, 19–22 June 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948. Accessed November 11, 2015: http://www.who.int/about/definition/en/print.html

World Health Organization (WHO). (2005). *Strengthened health systems save more lives: An insight into WHO's European health systems' strategy*. The World Health Organization Regional Office for Europe, Denmark. Accessed July 3, 2014: http://www.euro.who.int/__data/assets/pdf_file/0011/78914/healthsys_savelives.pdf

World Health Organization (WHO). (2011). *Protecting Health from Climate Change: Vulnerability And Adaptation Assessment*. World Health Organization, 72.

Yates, R. (2014). Recycling fuel subsidies as health subsidies. *Bulletin of the World Health Organization* **92**, 547–547A.

Ziska, L., Knowlton, K., Rogers, C., Dalan, D., Tierney, N., Elder, M. A., and Frenz, D. (2011). Recent warming by latitude associated with increased length of ragweed pollen season in central North America. *Proceedings of the National Academy of Sciences of the United States of America* **108**(10), 4248–4251. Accessed August 1, 2014: http://doi.org/10.1073/pnas.1014107108.

Chapter 10 Case Study References

Case Study 10.1 Participative Development of a Heat-Health Action Plan in Ahmedabad, India

Ahmedabad Municipal Corporation (AMC). (2013). Ahmedabad Heat Action Plan. Guide to Extreme Heat Planning in Ahmedabad, India. Accessed August 30, 2015: http://www.egovamc.com/downloads/healthcare/healthpdf/heat_action_plan.pdf

Ahmedabad Municipal Corporation (AMC). (2015). Ahmedabad Heat Action Plan. Guide to Extreme Heat Planning in Ahmedabad, India. Accessed December 27, 2014: http://www.ndma.gov.in/images/pdf/HAP2015.pdf

Ahmedabad Urban Development Authority (2016). Accessed January 29, 2017: http://www.auda.org.in/Content/about-us-42

Census Bureau of India (2011). Population Census 2011. Accessed February 4, 2016: http://www.census2011.co.in/

Government of India. (2011). Census of India. Registrar General & Census Commissioner, India, New Delhi. Accessed July 28, 2015: http://censusindia.gov.in/

Knowlton, K., Kulkarni, S. P., Azhar, G. S., Mavalankar, D., Jaiswal, A., Connolly, M., Nori-Sarma, A., Rajiva, A., Dutta, P., Deol, B., Sanchez, L., Khosla, R., Webster, P. J., Toma, V. E., Sheffield, P., and Hess, J. J., the Ahmedabad Heat and Climate Study Group (2014). Development and implementation of south Asia's first heat-health action plan in Ahmedabad (Gujarat, India). *International Journal of Environmental Research and Public Health* 11, 3473–3492. doi:10.3390/ijerph110403473.

Kotkin, J. (2010). The world's fastest growing cities. Forbes. Accessed October 28, 2015: http://www.forbes.com/2010/10/07/cities-china-chicago-opinions-columnists-joel-kotkin.html.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., Olwoch, J. M., Revich, B., and Sauerborn, R. (2014). Human health: Impacts, adaptation, and co-benefits. In Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* (709–754). Cambridge University Press.

Tran, K. V., Azhar, G. S., Nair, R., Knowlton, K., Jaiswal, A., Sheffield, P., Mavalankar, D., and Hess, J. (2013). A cross-sectional, randomized cluster sample survey of household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. *International Journal of Environmental Research and Public Health* 10, 2515–2543. doi:10.3390/ijerph10062515.

World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

Case Study 10.2 Health and Social Cost of Disaster: Nova Friburgo, State of Rio de Janeiro, Brazil

Instituto Brasileiro de Geografia e Estatística (IBGE). (2015). Population Census. *Cidades/Rio de Janeiro/Nova Friburgo*. Accessed January 25, 2016: http://cidades.ibge.gov.br/

Instituto Oswaldo Cruz-Fiocruz. (2013). *Social Cost Estimate of Hydrological Disaster in Nova Friburgo (RJ) – Health Sector*. IOC/Fiocruz,.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.

Pereira, C. A. R., Barata, M. M. L., and Trigo, A. M. (2014). Social cost of leptospirosis cases attributed to the 2011 disaster striking Nova Friburgo, Brazil. *International Journal of Environmental Research and Public Health* **11**, 4140–4157.

World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

Case Study 10.3 Windsor Heat Alert and Response Plan: Reaching Vulnerable Populations

City of Windsor. (2013). Stay Cool Windsor-Essex Heat Alert and Response Plan. Accessed December 23, 2014: www.windsorfire.com/wp-content/uploads/2013/08/Heat-Alert-Response-Plan.pdf

Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E., and Hémon, D. (2006). Excess mortality related to the August 2003 heat wave in France. *International Archives of Occupational and Environmental Health* **80**(1), 16–24.

Government of Canada. (2015). Population and dwelling counts, for Canada and census subdivisions (municipalities), 2011 and 2006 censuses. Accessed February 3, 2016: http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/hlt-fst/pd-pl/Table-Tableau.cfm?LANG=Eng&T=301&S=3&O=D

IPCC. (2014). Summary for policymakers. In Field, C. B., V. R. Barros, D. J. Dokken, K. J.

Mach, M., Mastrandrea, D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L. (eds.), *Climate Change 2014. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (1–32). Cambridge University Press.

Oke, T. R. (1997). Urban climates and global change. In Perry A., and Thompson R. (eds.), *Applied Climatology: Principles and Practices*. Routledge.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.

Robine, J., Cheung, S., Le Roy, S., Michel, J., and Herrmann, F. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus – Biologies* **331**(2), 171–178

World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

Case Study 10.4 Health Impacts of Extreme Temperatures in Brisbane, Australia

Australian Bureau of Statistics (ABS). (2011a). *Census of Population and Housing*. Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics (ABS). (2011b.) *Queensland Australian Statistical Geography Standard (ASGS) Edition 2011*. Australian Bureau of Statistics, Canberra.

Huang, C., Barnett, A. G., Wang, X., and Tong, S. (2012). The impact of temperature on years of life lost in Brisbane, Australia. *Nature Climate Change* **2**(4), 265–270.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.
World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

Case Study 10.5 Kedarnath: Flood and Humanitarian Loss in Uttarakhand Districts in India

Census Bureau of India (2011). Population Census 2011. Accessed February 24, 2015: http://www.census2011.co.in/
Dube, A., Ashrit, R., Ashish, A., Sharma, K., Iyengar, G.R., Rajagopal, E.N., and Basu, S. (2013). Performance of NCMRWF Forecast models in predicting the Uttarakhand Heavy Rainfall Event during 17–18 June 2013. National Centre for Medium Range Weather Forecasting, Ministry of Earth Sciences. Accessed February 3, 2016: http://www.ncmrwf.gov.in/KEDARNATH_REPORT_FINAL.pdf
Dube, A., Ashrit, R., Ashish, A., Sharma, K., Iyengar, G. R., Rajagopal, E. N., and Basu, S. (2014). Forecasting the heavy rainfall during Himalayan flooding-June 2013. *Weather and Climate Extremes* 4, 22–34.
Indian Express. (2013). Uttarakhand yet to implement water management act. Accessed June 16, 2014: http://archive.indianexpress.com/news/uttarakhand-yet-to-implement-water-management-act/1147808/
Munich Re (2014). *Natural catastrophes* 2013: Analyses, assessments, positions. Topics Geo, 2013. Accessed June 9, 2015: http://www.munichre.com/site/corporate/get/documents_E1043212252/mr/assetpool.shared/Documents/5_Touch/_Publications/302-08121_en.pdf
Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.
World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

Case Study 10.6 Kunshan Eastern Health Care Center, Kunshan City, China

Hairong, W. (2016). An inspiring visit. *Beijing Review* 26, June 30. Accessed February 24, 2017: http://usa.bjreview.com/Arts/201606/t20160628_800060747.html
Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.
U.S. Green Building Council. (2010, updated 2014). LEED 2009 for Healthcare. USGBC, Washington, D.C. Accessed July 23, 2015: http://www.usgbc.org/sites/default/files/LEED%202009%20RS_HC_4–2014_cover.pdf
World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD