

HEALTH SYSTEM ADAPTATION TO CLIMATE VARIABILITY AND CHANGE

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Executive Summary

Climate change is already causing avoidable injuries, illnesses, and deaths, and is damaging healthcare and public health facilities. The magnitude and distribution of future climate-sensitive health outcomes and of risks to health systems will depend on the level and timing of investment in adaptation and on the chosen greenhouse gas emission pathway. If no additional actions are taken, then over the coming decades substantial increases in morbidity and mortality are expected, as well as breakdowns of health and social services.

Climate-sensitive health outcomes include injuries, illnesses, and deaths associated with extreme weather and climate events, such as floods and heatwaves, or with changes in air quality; increases in the geographic range, seasonality, and/or intensity of transmission of infectious diseases such as diarrheal disease, vectorborne diseases (e.g., Lyme disease, dengue and malaria); undernutrition; and health consequences associated with diffuse, delayed, and/or cascading effects of climate change or the actions taken to prepare for and address risks (e.g., occupational impacts, undernutrition, conflict, migration, and mental stress and morbidity).

The health risks of climate change are and will continue to be distributed inequitably, with vulnerable populations and regions differentially affected. Some population groups (e.g., older adults, people with chronic illnesses, people with mobility challenges, the poor and isolated, Indigenous populations, certain occupational groups, and women and girls) will suffer from a disproportionate share of the impacts because of heightened physiological sensitivities, greater exposures, or less capacity to take protective actions. Low- and middle-income countries (LMICs) face more severe impacts because of current vulnerabilities such as underlying levels of disease, limited infrastructure and

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services, poverty, weak economies, poorly informed governance and decision-making processes, and geographic locations affected by floods, droughts, sea level rise, and other climate-related hazards.

The foundations for future adaptation already exist in current health policies and programs for managing climate-sensitive health outcomes, and health systems are increasingly mainstreaming climate change adaptation into policies and programs at local to national scales, although this is highly dependent on the governance context as well as on the available financial and human resources. However, successful adaptation will require development, implementation, evaluation, and modification of interventions to increase their effectiveness in the face of ongoing climate and societal change.

A major challenge is that current funding for health adaptation is negligible (<1% of international climate adaptation finance). This led the 2018 Adaptation Gap Report to conclude *“there is a significant global adaptation gap in health, as efforts are well below the level required to minimize negative health outcomes”*. This is despite the fact that health is a priority in 54% of Nationally Determined Contributions (NDCs) and nearly all National Adaptation Programmes for Action (NAPAs). Research funding to understand and manage the health risks of climate change is even smaller than the <1% of adaptation funding designated for health (discussed later).

Strengthening health systems and protecting and promoting population health are needed to increase resilience, including the following key components of health systems: (1) a health workforce with knowledge and tools to promote climate resilience; (2) health information systems that support effective management of the health risks of climate change, such as early warning systems; (3) effective service delivery; and (4) adequate financing, including attention to financing in other sectors (e.g., property insurance) to limit indirect health effects (e.g., effects of catastrophic household losses from extreme weather events and mental morbidity). Broad-based resilience, including climate-sensitive social development, is needed that considers synergies and trade-offs of actions in other sectors.

Moreover, progress on achieving the Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction would substantially contribute to increasing health system resilience.

Effective adaptation options are available for deployment at scale within existing health and health-determining sectors, and can be further enhanced through research and development. Nonetheless, limits to adaptation exist, including human physiological tolerance to high temperatures and cascading losses and impacts for mental and physical health. Sensitivity of complex ecosystems essential to human health and wellbeing strongly indicate there are limits to adaptation and underline the need to pair adaptation with strong mitigation measures to safeguard lives and health. Well-chosen mitigation measures can bring significant co-benefits to human health, and synergies with adaptation.

Recommendation 1: Raise national investments in climate change and health research to more than 1% of health and social research budgets in high-income countries and 5% in middle-income countries, and investments in health adaptation for population health and health system resilience to at least 5% of multilateral, bilateral, and donor adaptation funding for LMICs. Further, national or international funding should be provided for countries to include a health representative in their UNFCCC delegation, to strengthen high-level awareness and advocacy.

Recommendation 2: Develop and fund scenario-based and integrated adaptation plans within health systems and across sectors that account for the multiple and interacting risks of climate variability and change on all aspects of human and natural systems. This involves (1) mainstreaming climate change environmental impacts and scenarios of social impacts into all relevant health policies and programs; (2) mainstreaming health into all climate change-relevant policies; (3) developing systems-based adaptation approaches within a region, explicitly exploring and managing possible synergies and trade-offs across sectors, and taking into account risks outside recent experience; and (4) attending explicitly to infrastructure adaptation needs in health and other sectors when infrastructure is essential to population health.

Recommendation 3: Enhance the capacity for aggressive adaptation actions. Innovative and participatory mechanisms and fora should be developed to facilitate the uptake of research findings into policies and practice. This includes designing adaptation projects to efficiently identify lessons learned and best practices so they can be shared more readily across regions and sectors. Ensuring

stakeholder engagement throughout developing, implementing, monitoring, and evaluating health adaptation projects can increase effective uptake; this should include engagement with particularly vulnerable communities and populations, such as Indigenous populations.

Recommendation 4: Develop new technologies for health adaptation, from new vaccines to big data and artificial intelligence approaches to managing climate-related risks. In addition to increasing the implementation of adaptation measures, new technologies and tools will be needed to protect and promote health in a changing climate, and to address concerns about, for example, declining worker productivity with higher temperatures, increases in the geographic range of vectorborne diseases, and increases in undernutrition because of changes in the nutritional quality of key cereal crops.

Recommendation 5: Promote the development of zero emission technologies that reduce traditional air pollution, to reduce the level of adaptation required today and in the future; and facilitate technology transfer to LMICs.

Introduction

Climate change is adversely affecting population health and health systems. Future changes in weather patterns, sea level rise, and ocean acidification are projected to primarily increase the numbers of injuries, illnesses, and deaths from climate-sensitive health outcomes, and to affect the functioning of public health and health care systems.¹ The burden and distribution of future climate-sensitive health outcomes and of risks to health systems will depend on the level and timing of investment in adaptation and on the greenhouse gas emission pathway that is chosen. If no additional actions are taken, then over the coming decades, substantial increases in morbidity and mortality are projected.

Healthy populations, and by extension health systems, are critical for any country's long-term quality of life and economic growth and development; health systems also can be a burden on the economy. The costs of ill health include resource costs (health and social treatment costs, such as hospital admissions); opportunity costs (lost work hours); and welfare costs or disutility (pain or suffering, concern, and inconvenience to family and others).² For example, six major weather- and climate-driven events struck the United States between 2000 and 2009 including

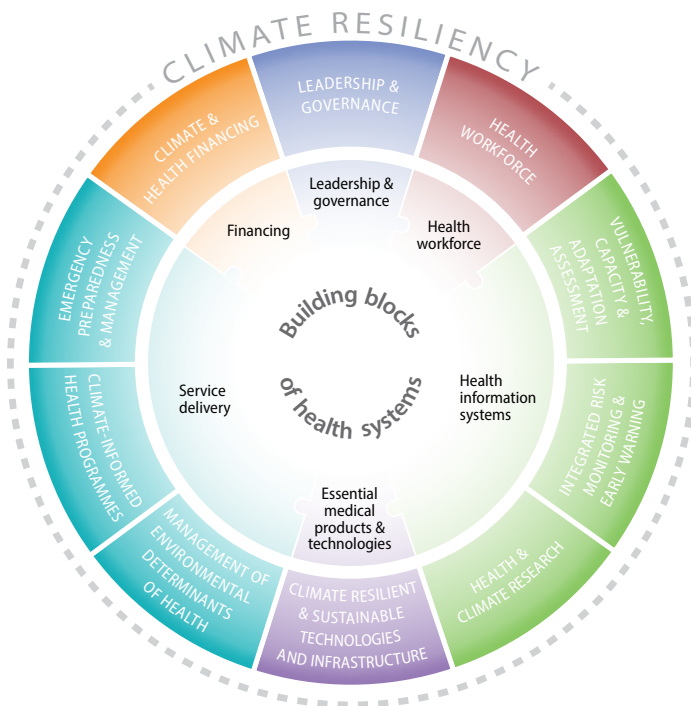
the 2002 outbreak of West Nile virus in Louisiana, the 2003 Southern California wildfires, the 2004 Florida hurricane season, the 2006 California heatwave, the 2009 flooding of the Red River in North Dakota, and higher concentrations of ground-level ozone. In total, these events increased health care costs to an estimated US\$740 million, reflecting more than 760,000 encounters with the health care system.³ The total health costs, including 1,689 lives lost prematurely (valued using nonmarket economic values), exceeded US\$14 billion. While the United States could absorb these costs, economic growth in LMICs can be significantly affected by the consequences of high climate-related burdens of malaria, diarrheal disease, and undernutrition that impact child growth and development, and associated resource, opportunity, and welfare costs.⁴ For example, Hurricane Pam struck Vanuatu in 2015 resulting in up to 70% of the population of 277,000 displaced. Initial concerns about food security, shelter, immunization, and access to safe water were eventually replaced with reconstruction and recovery.⁵ Tourism and agricultural output were severely affected, reducing economic output in 2015 by US\$37 million.

The term 'health systems' refers to the organizations of people, institutions, and resources that work to protect and promote population health. Two main functions of health systems are population health and health care, where population health is the science and art of preventing ill health, prolonging life, and promoting health by identifying the causes of disease and disability and by identifying solutions at the scale of communities and populations.⁶ The exact configuration of health services varies across countries, but all incorporate components to strive for effective public health prevention, including leadership and governance; knowledge (e.g. surveillance, monitoring, and evaluation, and research); protection through international health regulations; promote actions to address inequalities and the social, economic, and environmental determinants of health; primary prevention; primary healthcare; advocacy; and workforce development.^{7,8}

Embedded within these basic health services are components required for mainstreaming climate change into health sector policies and plans, to build a climate-resilient health system (Figure 1). The World Health Organization (WHO), international, multi-lateral, and bilateral agencies, non-governmental organizations, and ministries of health are using this framework to facilitate and focus adaptation

Ten components comprising the WHO operational framework for building climate resilient health systems.⁹

FIGURE 1



efforts to transform health systems to be more resilient and sustainable, taking into consideration challenges and opportunities at the local level.

Material Risks

Population Health

Climate change can affect health through multiple pathways.¹⁰

- Changes in the frequency, intensity, and duration of extreme weather and climate events, including heat, windstorms, flooding, and drought that directly injure health;
- Effects mediated through natural systems, for example, changes in the geographic range and incidence of infectious diseases (for example, water-, food-, and vectorborne diseases) and health outcomes associated with poor air quality (e.g., high concentrations of ozone, particulate matter, dust, aeroallergens); and
- Effects heavily mediated by human systems (e.g., occupational impacts, undernutrition, conflict, migration, and mental stress).

Climate-sensitive health outcomes include injuries, illnesses, and deaths associated with extreme weather and climate events, such as floods and heatwaves, or with changes in air quality; increases in the geographic range, seasonality, and/or intensity of transmission of infectious diseases such as diarrheal disease, vectorborne diseases (e.g., Lyme disease, dengue, and malaria); and health consequences associated with diffuse, delayed, and/or cascading effects of climate change or the actions taken to prepare for and address the risks (Figure 2).^{11,12,13}

Changes in the mean and variance of weather and climate variables can independently and jointly influence the burden of climate-sensitive health outcomes. For example, rising mean temperatures can create conditions conducive to the geographic spread of vectorborne diseases such as malaria.¹⁴ At the same time, heavy precipitation events can wash away breeding grounds, resulting in short-term reductions in the number of malaria-transmitting *Anopheles* mosquitoes in endemic areas, but can also provide mosquito breeding habitat in places where mosquitoes and malaria were previously uncommon, increasing morbidity and mortality in populations that have not previously been exposed, and therefore have low immunity. As changes continue over the century, and as underlying population health status and health system capacity shifts, thresholds may be crossed that could result in large increases or decreases in the incidence of climate-sensitive health outcomes.

Some climate change health impacts are relatively immediate, such as morbidity and mortality during a heatwave, and some are delayed. Delayed effects include mental health impacts following extreme weather and other climate events.¹⁵ They can also include an increase in childhood undernutrition due to reduced agricultural yields following drought and/or excessive flooding, and decreased nutritional quality of food from higher atmospheric carbon dioxide concentrations. Cascading effects from extreme events can disrupt access to health and social services. Estimates of the overall health burden of climate change are almost certainly underestimates because of the complexity of the causal pathways between climate-related hazards and health outcomes and a lack of robust surveillance and monitoring systems in many countries. Data tend to be weakest in the countries that are at greatest risk, increasing the challenges.

A small number of detection and attribution studies show that climate change is causing specific health impacts,¹⁷ with risks projected to increase with each additional unit of warming.¹⁸ All climate-sensitive health outcomes are

current challenges for health systems (Table 1). Near-term opportunities exist for better management and, absent adaptation, future additional disease burdens will be strain on health system resource capacity.

FIGURE 2 Major health risks associated with climate change.¹⁶

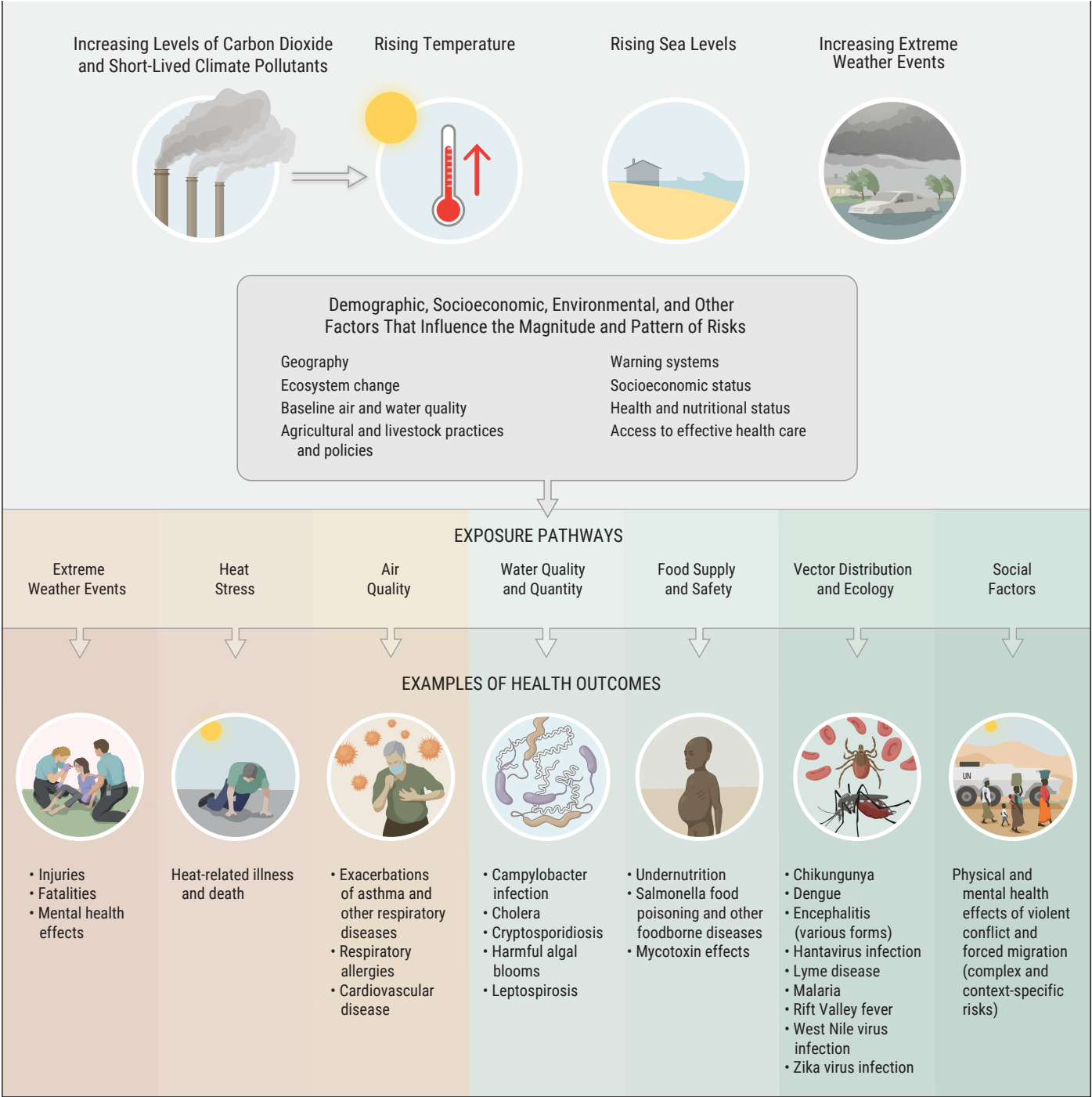


Table 1: Selected climate-sensitive health outcomes and current burden of disease.^{19,20,21,22,23,24}

Health outcome	Present distribution	Population at risk	Annual morbidity or mortality
High ambient temperature morbidity and mortality	Worldwide	Everyone, but particularly older adults, those with chronic health conditions, the isolated, and those without access to cooling shelters or air conditioning	Global estimates not available
Ozone-related mortality	Primarily urban areas worldwide	Older adults, children, those with respiratory diseases	About 1 million deaths in adults over age 30 years
Diarrheal disease mortality	Primarily tropical regions	Children with limited access to safe water and improved sanitation	About 480,000 children die annually
Malaria	Tropical regions	About 50% of the world population	In 2017, 219 million cases and 435,000 deaths
Dengue	Tropical regions, spreading into temperate regions	About 33% of the world population	About 400 million cases
Lyme disease / Lyme borreliosis	Temperate forested regions through North America, Europe, and Northern Asia	Most common tickborne disease in the Northern Hemisphere	About 365,000 cases in the United States and Europe
Undernutrition	Africa / Latin America / Asia	Primarily children	151 million children stunted (22% of children) and 50.5 million wasted (7.5%)

National and subnational health systems have policies and programs to manage these health risks, although management efforts are inadequate in many settings. In addition, because many programs were not originally designed to take climate change into account, ministries and departments of health are largely unprepared to adapt to a changing climate. Without significant adaptation investments and policies to promote proactive and effective measures, heat-related morbidity and mortality, ozone-related mortality, some vectorborne diseases, particularly in Africa and Asia, and undernutrition are projected to increase with warming of 1.5°C and higher.²⁵ For example, one study modeled the health effects associated with expected reductions in food availability and projected a net increase of 529,000 deaths globally by 2050 due to climate change.²⁶ Another study of 23 countries suggested that under a high greenhouse gas emissions scenario, a 3 to 12% net increase in temperature-related mortality could be expected to occur without further adaptation from the period 2010-2019 to 2090-2099.²⁷ Climate change also could increase the number of people in extreme poverty by 100 million people by 2030 without concerted efforts to include climate resiliency initiatives into development practices.²⁸ The likelihood of crossing thresholds increases substantially with warming of 3°C and above, which is expected to lead to a stark increase in the burden of disease attributable to climate change.

Overall, a substantial proportion of the number of projected climate-related injuries, illnesses, and deaths, and of decrements to quality of life, are preventable for warming of less than 2-3°C through more proactive and effective adaptation, acknowledging high levels of diversity across and within countries. Incorporating estimates of possible future adaptation into projections of health impacts reduces the magnitude of the estimates of risk. However, current adaptation projects are more incremental than transformational, suggesting that these efforts are unlikely to adequately address future health risks. Very large health benefits may also be achieved through aggressive mitigation efforts that reduce the likelihood of even more dangerous interference with the climate system, although the several decade-long lag between significant mitigation actions and a noticeable shift in the trajectory of climate change is a challenge to politicians and policy-makers at all levels.

Vulnerable Populations

The health risks of climate change are and will continue to be distributed inequitably, with vulnerable individuals and populations and regions differentially affected, compounded by projected concurrent increases in poverty and inequalities.^{29,30} Some population groups in all countries (e.g., older adults, people with chronic illnesses, people with mobility challenges, the poor and isolated, Indigenous populations, certain occupational groups) will suffer from a

disproportionate share of the impacts. Women and children are often at highest risk because of heightened physiological sensitivities, greater exposures, and/or less capacity to take protective actions. LMICs face more severe impacts because of current vulnerabilities such as underlying levels of disease, limited infrastructure and services, weak economies, insufficient emergency management, limited insurance coverage and funds for recovery after disasters, and poorly informed governance and decision-making processes.^{31,32} The magnitude and pattern of future vulnerabilities will depend on development choices affecting the societal context that will interact with climate change; that is, development choices will affect adaptation needs, barriers, and opportunities.^{33,34} For example, the degree of access to safe water and improved sanitation will alter vulnerability to temperature- and precipitation-related increases in diarrheal diseases.

Public Health and Health Care

Public health and health care are the first and last defense for protecting health from climate change; the first as they are critical for prevention either through reducing greenhouse gases or by contributing to community resiliency efforts, and the last through the treatment and care they provide to affected people when exposed to climate hazards. Recent events demonstrated that health facilities can be seriously impacted by climate hazards, for example from increases in temperature and humidity that close operating rooms, ice storms that cause transportation disruptions, tropical storms and hurricanes that disrupt services through flooding and wind damage, wildfires that compromise air quality due to long-distance smoke dispersal, and permafrost melt that impacts structural integrity.³⁵ In a recent global survey of 478 cities, 51% of respondents indicated that they expect climate change to “seriously compromise” public health infrastructure.^{36,37}

Many health systems operate with very little surge capacity, which is problematic in the context of growing risks from shocks and stresses related to climate change. For instance, following the passing of Tropical Cyclone Pam in Vanuatu in 2015, the destruction of health care infrastructure combined with low numbers of health and social personnel and difficulties mobilizing resources and funds, significantly impacted the capacity of health services to deliver curative and preventive services.^{38,39} Similarly, addressing mental health needs of people after climate-

related disasters can be very challenging and costly.^{40,41} For example, after Superstorm Sandy struck the New York area in 2012, the odds of Post-Traumatic Stress Disorder (PTSD), depression, and anxiety were higher among individuals without access to care.⁴²

State of Adaptation

Health systems are accountable to manage the health risks of changing climate because most of the likely health outcomes of concern are familiar problems with, in most cases, at least some evidence base regarding effective risk reduction strategies. However, successful adaptation will require development, implementation, evaluation, and modification of interventions to increase their effectiveness to ongoing climate and societal change, and rapidly scaling up effective measures. The foundations for future adaptation already exist in current policies and programs for managing infectious diseases (including emerging infectious diseases), undernutrition, maternal and child health, *inter alia*, and there is relevant expertise with evaluation and implementation from other disciplines. However, decision-makers need location-specific information on hazards, exposures, vulnerabilities, and capacities to inform decisions. With leadership and guidance from WHO,⁴³ the Lancet,⁴⁴ and the actions of individual nations and organizations,⁴⁵ efforts are increasing among health authorities to prepare for climate change. Some progress is being made in low-income countries to undertake needed actions, for example, increased access to improved water sources and sanitation, immunization, and electricity.^{46,47} In addition, health systems are beginning to mainstream climate change adaptation into policies and programs at local to national scales, both within the formal health sector and through integrating climate risk into key related sectors, for example through roll-out of climate-resilient water safety planning. However, this is highly dependent on the governance context as well as on the available financial and human resources.

There is evidence that adapting to the health risks of climate change can be effective.^{48,49} Important prerequisites for enhancing effectiveness include (1) understanding how climate change causes or enhances ill health, (2) recognition by decision-makers that the problem matters, (3) possession of the capability to influence policies and programs, and (4) the political will to commit scarce resources to the issue. These prerequisites are comparable

to the determinants of adaptive capacity and highlight the win-win opportunities of investing in health systems and the flow-on effects this may have on adaptive capacity, and *vice versa*.⁵⁰

Current health policies and programs, many of which were not developed and deployed with consideration of climate change, need to be strengthened to adequately and proactively manage changes in the magnitude and pattern of expected climate-related health risks. For example, in certain regions, malaria control programs will need to consider how climate change could alter the geographic range of the vector and disease, and the seasonality and the intensity of transmission, to maintain their current level of effectiveness.⁵¹ Just maintaining the effectiveness of current health policies and programs as the climate continues to change may require considerable investments. One estimate projected that the vulnerability of adults over the age of 65 years would need to be reduced by about 75% in southern Europe to maintain current rates of heat-related mortality under RCP4.5.⁵²

Actors outside of national health systems, including donors and development partners, non-governmental organizations (NGOs), families, and individuals also play critical roles in effective adaptation. Health adaptation projects are being funded, albeit sparsely and at a very low level, by donors and development partners; these projects typically focus on building the capacity of health systems. NGOs such as the Red Cross/Red Crescent Societies and Health Care Without Harm are advancing adaptation on climate change through, for example, raising awareness, training, and capacity building. A constant struggle is the chronic underfunding of health services, leaving national and local health systems with too few resources to effectively address multiple competing demands.

Limits to adaptation will become increasingly evident with additional climate change, from the extent to which individuals can physiologically tolerate ever increasing temperatures, to crossing ecological thresholds that lead to a rapid and unexpected increase in the geographic range of certain vectorborne diseases, to the mental wellness challenges of forced migration. There has been little

consideration of limits to adaptation in population health and health systems.

Actors Undertaking Health Adaptation

Multiple actors at local to international levels are initiating adaptation to the health risks of climate change. These actions can be categorized as reducing exposures and vulnerabilities to prevent the onset of adverse health outcomes and reducing morbidity and mortality once people are impacted.⁵³ The specific actions range from autonomous adaptation (e.g., wearing appropriate clothing, limiting strenuous activity, and drinking sufficient water during a heatwave), to education and training for health care workers and the public, to intersectoral technical solutions (e.g., vector control programs, urban planning), and legislative actions (e.g., regulations to control emissions leading to the formation of ground-level ozone). Importantly, actions at the community level often determine the risks that individuals are exposed to and, in many cases, the range of possible actions that individuals can take to reduce their own risks. The level of ambition for health adaptation needs to be significantly increased to prepare for projected health risks.

Individual adaptation actions range from autonomous actions such as installing cooling mechanisms (e.g., fans and air conditioning) to increase thermal comfort during heatwaves, to using insecticide-treated bednets during malaria transmission season. However, many of these adaptations assume the individual or family will bear the behavioural and economic costs for implementation and upkeep, which may be unduly burdensome or unaffordable for poor populations in all countries. This also raises equity issues if individuals and families in countries who make small contributions to global greenhouse gas emissions are expected to bear the costs of coping with the impacts that arise from the actions of countries whose total greenhouse gas emissions are high.

Table 2 provides examples of actors and their potential adaptation roles and responsibilities to reduce risks from extreme temperature and weather events, and vectorborne diseases.

Table 2: Actors and their roles and responsibilities in health adaptation: extreme temperature and weather events, and vectorborne diseases.⁵⁴

Actor	Reduce exposures	Prevent disease onset	Reduce morbidity and mortality
Extreme temperature and weather events			
Individuals	<ul style="list-style-type: none"> Stay informed about impending weather events Follow guidance for emergency preparedness 	Follow guidance for conduct during and following an extreme event (e.g., seek cooling centers during a heat-wave or evacuate during a hurricane / typhoon)	Seek treatment when needed
Community, state/provincial, national agencies, and international development and humanitarian actors	<ul style="list-style-type: none"> Provide scientific and technical guidance for climate resilient building and infrastructure standards Enforce building and infrastructure standards 	<ul style="list-style-type: none"> Develop scientific and technical guidance and decision support tools for development of early warning systems and emergency response plans, including appropriate individual behavior Implement early warning systems and emergency response plans Conduct tests of early warning systems and response plans before events Conduct education and outreach on emergency preparedness Educate and train health professionals Develop and update vulnerability maps for climate-sensitive health outcomes 	<ul style="list-style-type: none"> Ensure that emergency preparedness plans include health and social services Monitor the air, water, and soil for hazardous exposures Collect, analyze, and disseminate data on the health consequences of extreme events and heatwaves Monitor and evaluate the effectiveness of systems Provide social services to, e.g., prevent / alleviate mental health problems; and provide access to climate-resilient buildings
NGOs and other actors	Increase awareness of the health risks of climate change, including those related to extreme weather events, and the need for robust greenhouse gas mitigation measures	NGOs and other actors play critical roles in emergency preparedness and disaster relief	Education and training of health professionals on risks from extreme weather events
Vectorborne diseases			
Individuals	Take appropriate actions to reduce exposure to infected vectors, including eliminating vector breeding sites around residence	Vaccinate for diseases to which one would likely be exposed	Seek treatment when needed
Community, state/provincial, and national agencies, and international development and humanitarian actors	<ul style="list-style-type: none"> Provide scientific and technical guidance and decision support tools for development of early warning systems Institute and maintain effective vector (and pathogen) surveillance and control programs Develop early warning systems for disease outbreaks Develop and disseminate information on appropriate individual behavior to avoid exposure to vectors 	<ul style="list-style-type: none"> Sponsor research and development on vaccines and other preventive measures Sponsor research and development on rapid diagnostic tools Provide low-cost vaccinations to those likely to be exposed 	<ul style="list-style-type: none"> Sponsor research and development on treatment options Develop and disseminate information on signs and symptoms of disease to guide individuals on when to seek treatment
NGOs and other actors	Increase awareness of the health risks of climate change, including those related to vectorborne diseases, and the need for robust greenhouse gas mitigation measures	Share best practices between actors	Build the capacity of health systems to manage the risks of climate change for vectorborne diseases

Vulnerability, Capacity, and Adaptation Assessments

Most countries and sub-national organizations begin the adaptation process with conducting vulnerability, capacity, and adaptation assessments (V&A assessments), followed by developing the health component of national adaptation plans (H-NAPs). In 2018, 92 countries had completed V&A assessments, with most LMICs requiring technical and financial support.⁵⁵

The World Federation of Public Health Associations (WFPHA) conducted a self-report survey that assessed the state of mitigation and adaptation activities in a snapshot of 35 countries.⁵⁶ The majority of respondent countries reported they have no comprehensive projections of the health risks of climate change. Unsurprisingly, least developed countries were less prepared, although most developed countries also lacked comprehensive national climate change action plans that include comprehensive health adaptation actions. Gaps exist in identifying vulnerable populations and infrastructure, and in assessing coping capacity and knowledge gaps.

A proposed next step toward proactive adaptation is to develop the needed tools, information and capacity for health authorities to conduct stress tests of the ability of health systems and services to prepare for and manage more severe climate change-related shocks and stresses.⁵⁷ Health systems are regularly exposed to and prepared for shocks and stresses not related to climate change, such as pandemics, demographic and lifestyle changes (e.g., population aging; vaccine hesitancy), financial crises, understaffing or lack of a skilled work force, and others. Climate-related shocks and stresses affect population health and health systems through myriad pathways, including direct losses of lives, livelihoods, and infrastructure, and by draining funds from investments in social and economic development to, for example, emergency relief and reconstruction. The impacts can be cumulative and/or compounding until a tipping point is reached, resulting in significant changes in the affected system and severe health outcomes among the population, as for example in Europe in 2003, when over 70,000 excess deaths occurred during a heatwave.⁵⁸ Climate change-related shocks and stresses may compound issues, as illustrated by a recent heatwave in Quebec that interacted with the challenges of

reaching vulnerable and socially isolated individuals, resulting in 66 fatalities.⁵⁹ In another example, persistent drought and food insecurity in Syria, coupled with social-political and religious tensions, contributed to civil conflict, mass displacement, and a public health crisis.⁶⁰ Developing tabletop exercises and other forms of simulation to conduct health system stress tests in low to high resource settings for climate-related impacts would be a significant next step in advancing health system climate preparedness.

Core Public Health Functions

The majority of adaptation activities in the health sector have focused on core public health functions (Figure 1), including enhancing surveillance and monitoring of impacts, issuing alerts for hazardous weather, and educating the public about protective behaviors. Greater efforts are beginning to be directed at developing climate resilience through a broader health systems approach, for example by improving health facility infrastructure and emergency preparedness and training of staff.⁶¹

Strengthening health systems and protecting and promoting population health are needed to increase resilience today and in the future, including the following key components:⁶² (1) a health workforce with knowledge and tools to promote climate resilience; (2) health information systems that support effective management of the health risks of climate change; (3) effective service delivery; and (4) adequate financing, including attention to financing in other sectors (e.g., property insurance) to limit indirect health effects (e.g., effects of catastrophic household losses from extreme weather events). In addition, strengthening linkages between the health sector and other sectors with activities that are important to maintaining population health status, such as water, energy, and food, are important to increasing health sector resilience.

Developing a health workforce with knowledge and tools to promote climate resilience includes activities such as education, training, and capacity building for health care providers, researchers, and practitioners; memoranda of understanding with meteorological services and other departments; and leadership and governance that explicitly incorporates climate change. Colleges and universities should develop courses, programs, and degrees in climate change and health, to train the next generation of health professionals.

Table 3: Selected examples of how public health monitoring and surveillance relate to climate change.

Routine data analysis from mandatory notifications
Pharmacy-based monitoring of prescription and non prescription drug sales or health-related data preceding diagnosis
Sentinel surveillance (e.g. collection and analysis of high-quality, accurate data at a geographic location, such as hospital admissions)
Vector surveillance (monitoring the geographic distribution of vectors)
Real-time surveillance (instantaneous data collections with dynamic and sequential data analyses, such as hospital admissions)
Mortality from infectious diseases
Syndromic surveillance (e.g. monitor emergency room admissions to symptoms indicative of infectious disease)

Health information systems that effectively manage the health risks of climate change will include activities such as integrated risk monitoring and evaluation, early warning and response systems, and incorporation of Indigenous and traditional knowledge into programs. Such systems will also facilitate surveillance for climate sensitive conditions and, where applicable, evaluation of interventions aimed at reducing climate change-related health risks.

Effective delivery of health services includes activities such as building climate-resilient and sustainable technologies and infrastructure, improving disaster risk management, modifying current and implementing new climate-informed health policies and programs, and the effective management of the environmental determinants of health. Attention to projected demographic shifts and potential local and international migration, to which climate-related hazards may contribute, will also be increasingly important in health sector adaptation activities.

Efforts to climate-proof health sector infrastructures such as hospitals and clinics can be effective in improving patient and staff safety during climate-related emergencies and can result in significant cost savings and reductions in greenhouse gas emissions reductions.^{63,64} For example, through an energy system transformation program initiated in 2008, the Gundersen Health System in the United States reduced annual CO₂ emissions from 70 million to 1.6 million pounds, particulate matter from 435,000 to

11,000 pounds, and mercury from 2.5 to 0.16 pounds by 2016, keeping their energy costs to below 2008 levels.⁶⁵

Health authorities require adequate financing to successfully prepare for climate change-related impacts. Limited information on the costs of health adaptation hinders robust global and national estimates of investment needs. The monetary benefits of preventing health impacts can be high as illustrated by the ratios of the economic benefits-to-costs for heatwave early warning systems for London (ratio = 11), Prague (ratio = 308), and Madrid (ratio = 913), with increasing benefits under a changing climate.⁶⁶ Infrastructure changes are necessarily more costly, although still cost-effective when measured against repair and recovery costs in the event of infrastructure loss from climatic hazards. In a recent study, significant cost savings and service delivery benefits were projected when comparing a scenario where a hurricane strikes a hospital that invested in making critical infrastructure more resilient (hardening and elevating infrastructure) versus a hospital that did not make such investments. This included avoidance of a 10% revenue loss from business interruption to the unprepared hospital and a 20% increase in costs due to major emergency repairs to the facility (versus a 5% increase due to minor repairs for the hospital that made investments) with overall savings of millions of dollars.⁶⁷

In part, because current funding for health adaptation is negligible (<1% of international climate adaptation finance), the 2018 UNEP Adaptation Gap Report concluded “*there is a significant global adaptation gap in health, as efforts are well below the level required to minimize negative health outcomes*”.⁶⁸ This is despite the fact that health is a priority in 54% of Nationally Determined Contributions (NDCs) and nearly all National Adaptation Programmes of Action (NAPAs).

Because climate change cuts across most programs within a ministry or department of health, it is necessary to mainstream climate change preparation and response activities into corporate-level policies and specific programs, and into broader national policies, to better manage climate-sensitive health outcomes. In some countries, climate change policy sits within the finance ministry or other centralized ministries, which may mean that specific impacts on health, and adaptation needs, are not accounted for.

Also needed are technology and knowledge transfer to ensure the latest understanding of changing weather patterns (including the magnitude and rate of change) is used across programs to design efficient and effective interventions.⁶⁹

To be effective in protecting population health in a changing climate, adaptation also must incorporate strategies to manage the upstream drivers of adverse health outcomes. For example, the upstream drivers of emerging infectious disease threats that occurred in Europe over the period 2008-2013 included travel, trade, tourism, and climate and other environmental changes; all are outside traditional health system policies and programs.⁷⁰ Climate change also affects 'non-health' sector issues known as the environmental and social determinants of health (and including economic, environmental, and political factors) that in many ways determine the magnitude and pattern of climate change-related risks.⁷¹ Awareness is growing of the need for health systems to engage more broadly across government ministries and organizations, with additional efforts needed to create the multi-sector governance for collaborative relationships and projects with departments, ministries, non-governmental organizations, and others with responsibilities for regulating and managing these upstream drivers.⁷² The need, and trend, for more integrated intersectoral approaches, applies at all scales. For example, at the international level, the 17 Sustainable Development Goals are driving a more integrated approach to development assistance, for example building climate resilience (SDG 13 on climate action) into water safety planning (SDG 6 on water on sanitation) to reduce risks of water-borne disease (SDG 3 on health). At the national to local level, the Standards Council of Canada and Health Canada are supporting the National Program for Playground Safety at the University of Northern Iowa with developing guidance on how to include temperature and comfort in standards for how playgrounds are built as part of efforts to make such infrastructures climate resilient across Canada. This information will inform updates to the Canada Standard Association's Children's Playspaces and Equipment Standard (CAN/CSA-Z614-14) so that municipalities, affordable housing providers, and schools can help ensure new and renovated playgrounds are cool and comfortable for children and caregivers in summer, thereby preventing injuries to children like burns from metal slides in hot weather.⁷³

Experiences with Health Adaptation

Over the last two decades health authorities in some locations have begun tackling climate threats to health and in preparing for a warmer world through increased awareness of risks to populations. Efforts have also resulted in more scientific research and assessments and development of new adaptation tools and methods and greater mobilization of the health community.⁷⁴ A review of the first five years of implementation (2008–2013) of multinational health adaptation projects in Albania, Barbados, Bhutan, China, Fiji, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Philippines, Russian Federation, Tajikistan, and Uzbekistan documented lessons learned and good practice examples to facilitate assessing and overcoming barriers to implementation and to scaling up.⁷⁵ Recommendations included that:

- National health plans, policies, and budget processes explicitly incorporate the risks of current and projected climate variability and change;
- Longer-term, multifaceted and collaborative approaches be adopted with supporting activities (and funding) for capacity building, communication, and institutionalized monitoring and evaluation;
- Projects should focus not just on shorter term outputs to address climate variability, but also on establishing processes to address longer term climate change challenges; and
- Opportunities for capacity development should be created, identified, and reinforced.

The analyses underscored that irrespective of resource constraints, ministries of health and other institutions working on climate-related health issues in LMICs need to continue preparations to prevent additional health burdens in the context of a changing climate and socioeconomic development patterns. They also underscored the importance of planning for scaling-up from the beginning of an adaptation project, and not as an afterthought.

International projects starting in 2019-2020 for 10 least developed countries in Asia (Bangladesh, Cambodia, Lao PDR, Nepal, Myanmar, Timor Leste) and the Pacific (Kiribati, Solomon Islands, Tuvalu, Vanuatu), funded by the Least Developed Country Fund under the UNFCCC, will focus on four main outcomes:

- Mainstreaming climate-related risk and resilience into health policy frameworks, strengthening coordination between ministries of health and other health-relevant departments and ministries (e.g., agriculture, meteorological services, disaster risk management), and strengthening the capacity of health decision-makers to better understand and integrate climate change risks in health planning and programs;
- Health information and climate early warning systems, including digitizing health records, strengthening integrated surveillance systems, and developing early warning systems where feasible;
- Enhancing health service delivery to effectively prevent and manage climate-sensitive health outcomes, improving disaster risk management, and climate-proofing select health care facilities; and
- Knowledge management and technical assistance; this is a regional component to facilitate knowledge exchange, identifying lessons learned, and scaling up.

Promoting Health in Adaptation Programs in Other Sectors

As discussed, many of the drivers of the health risks of climate change arise in other sectors, such as infrastructure, energy, transportation, agriculture, conservation, water, and food. Opportunities exist to promote and protect population health by ensuring adaptation policies and activities in those sectors explicitly address health. Examples are provided here for cities and for food security.

PROMOTING HEALTH IN CLIMATE ADAPTATION IN CITIES

Climate change is projected to have profound impacts on cities, including on infrastructures related to energy, water, transport, and buildings that will in turn have consequences for human health and well-being.⁷⁶ Heat-related extreme events, variability in precipitation, and sea level rise can directly affect urban populations. Also, the risk of dengue fever transmission is higher in cities.

An example of the challenges being increasingly faced by cities is heat stress. Future warming and urban expansion are expected to lead to more extreme heat stress. An additional 0.5°C of warming implies a shift from the upper

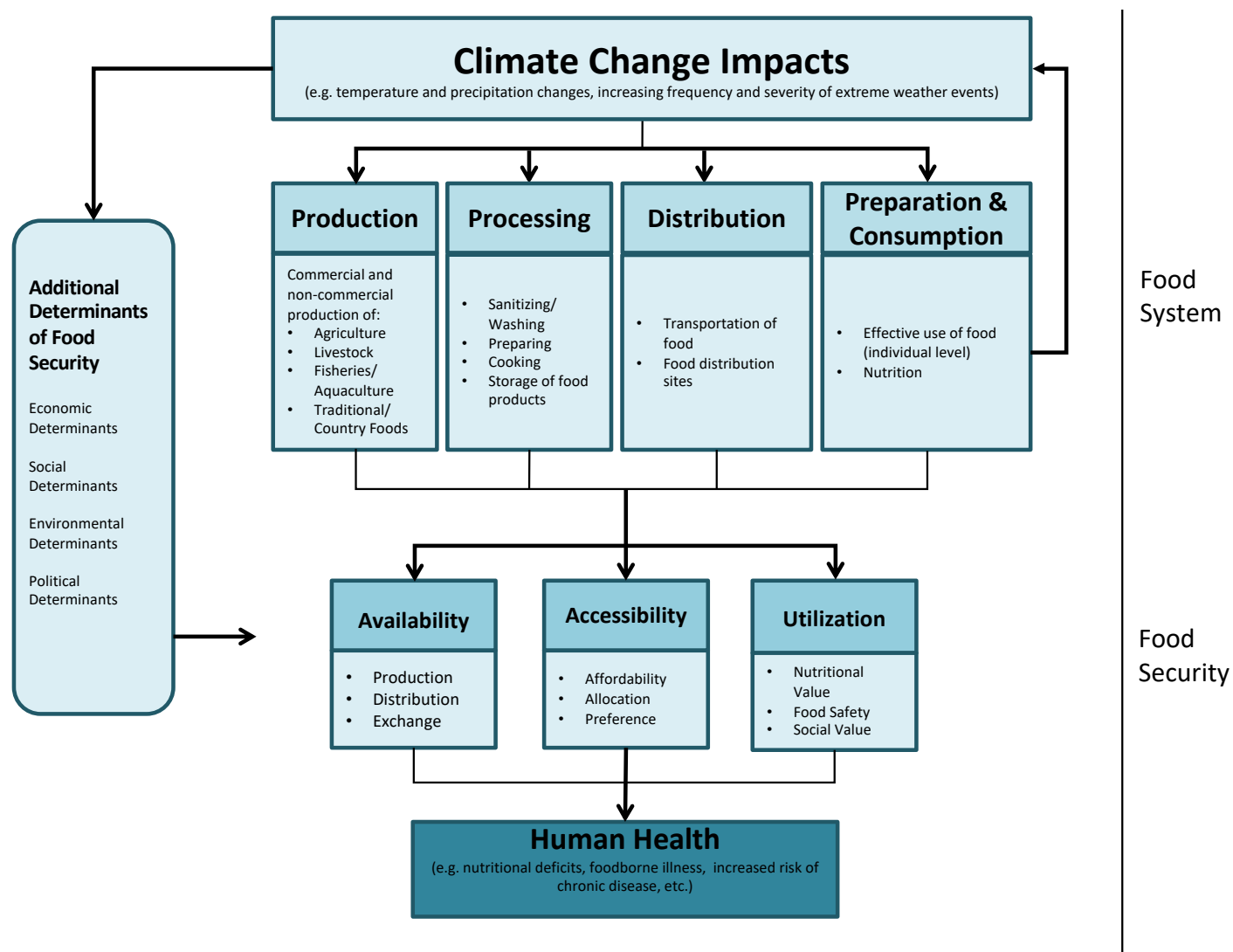
bounds of observed natural variability to a new global climate regime characterized by increases in the frequency, intensity, and duration of heatwaves.⁷⁷ Higher risks of heatwaves could occur in tropical coastal areas of Africa, South America, and Southeast Asia due to higher temperatures and because of large informal settlements, other vulnerable urban populations, and vulnerable assets, including businesses and critical urban infrastructure.⁷⁸

At 1.5°C of warming, more than 350 million people could be exposed to deadly heat by 2050 under a midrange population growth scenario, including megacities such as Lagos, Nigeria and Shanghai, China.^{79,80} Without considering adaptation options, such as more reflective roofs and other alterations to urban infrastructure,⁸¹ Karachi (Pakistan) and Kolkata (India) could experience conditions equivalent to those that led to the deadly 2015 heatwaves on an annual basis under 2°C of warming.^{82,83,84} Taking urban heat islands (UHI) into consideration, the occurrence and impacts of deadly heatwaves under 2°C of warming are projected to be substantially larger than under the present climate.^{85,86}

The experience of Ahmedabad, in Gujarat state, India, is instructive. After a devastating heatwave in 2010 that increased all-cause mortality by 40% over baseline levels,⁸⁷ the city government worked with its health sector and an international team to conduct a comprehensive risk assessment, expand and refine weather forecasting for the region, and develop a multi-sector heat action plan (HAP).⁸⁸ The HAP was piloted in 2013 and fully implemented in 2014. An evaluation of the program found that all-cause mortality associated with extreme heat was significantly reduced in the post-HAP period.⁸⁹ Based on these activities and the HAP's success, India's national government has generated HAP guidance⁹⁰ and over twenty of India's largest cities are in the process of developing and implementing HAPs of their own to reduce heat-related risks as the climate warms.

PROMOTING HEALTH IN ADAPTATION TO FOOD INSECURITY

Minimizing the risks to health from climate change impacts on food safety and security will require multi-sectoral collaboration. Food security exists when "...all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and health life".⁹¹



Food insecurity exists when any of the primary dimensions of food accessibility, availability and utilization, go unmet.

Climate change will affect global and domestic food systems.^{92,93} The IPCC Special Report on Warming of 1.5°C concluded that:⁹⁴

Limiting warming to 1.5°C compared with 2°C is projected to result in smaller net reductions in yields of maize, rice, wheat, and potentially other cereal crops, particularly in sub-Saharan Africa, Southeast Asia, and Central and South America, and in the CO₂-dependent nutritional quality of rice and wheat (high confidence). Reductions in projected food availability are larger at 2°C than at 1.5°C of global warming in the Sahel,

southern Africa, the Mediterranean, central Europe, and the Amazon (medium confidence). Livestock are projected to be adversely affected with rising temperatures, depending on the extent of changes in feed quality, spread of diseases, and water resource availability (high confidence).

Food security may become compromised should any key activities and operations of the food system experience disruption or stress.^{95,96,97} The pathways by which climate change can affect food systems and food security are complex (Figure 3).

Individuals who experience food insecurity are at an increased risk of developing nutritional deficiencies, poor

cardiovascular health, diabetes, oral health issues, and mental illness, and have a higher probability of becoming high-cost users of the health care system, thereby putting added stress on these services.^{99,100,101,102,103} Climate-related disruptions to the food system can indirectly impact human health by diminishing food security, which can have associated effects on physical and mental health and well-being.^{104,105} These impacts affect marginalized groups, such as Indigenous populations, women, and children more severely. Disruptions can affect regional and global food security by causing supply shocks and food availability issues as well as increased food prices.¹⁰⁶ Climate change increases the risk of simultaneous disruptions across the globe, which can compound and extend disruptions to supply chains. For example, half of the world's soybean supply could be cut off should ports along the Gulf Coast be disrupted at the same time as key road infrastructure in Brazil.¹⁰⁷

Further, higher concentrations of carbon dioxide are projected to reduce the concentrations of protein (about 10%), key micronutrients such as iron and zinc (about 5-10%), and B-vitamins (average of 30% for folate across multiple rice varieties) in wheat, rice, potatoes, and other cereal crops that feed hundreds of millions of people.^{108,109,110} Climate change can affect the growth, occurrence, and survival of food-borne pathogens, thus potentially affecting food security.¹¹¹ Another example is *Vibrio parahaemolyticus* in oysters harvested in British Columbia, Canada, which can cause severe gastrointestinal illness when ingested. Projections indicated that public health impacts caused by the bacteria could increase by 41-45% by the 2060s.¹¹²

A food system that is resilient to disruption and that has the capacity to adapt to climate change effects will strengthen food security and result in positive health outcomes. The effective functioning and operation of food systems is underpinned by collaboration of many different actors, including private and public stakeholders, spanning different geographic and time scales. Each sector is responsible for, and has jurisdiction over, different actions and activities that are part of the integrated food system. Successful adaptation requires involvement in planning by officials in a wide range of sectors such as agriculture, water, transportation, energy, physical infrastructure, urban planning, trade, community and family services, environmental conservation, and public health.

Research Needs

While there is enough evidence for significant concern regarding the health risks of climate change, there is limited evidence regarding specific health impacts in many locations, the most appropriate adaptation strategies to address these emerging threats, and how to most effectively and rapidly scale up these activities. There is very limited funding for research in these areas,^{113,114} constraining efforts to (1) provide insights into the projected magnitude and pattern of climate-sensitive health outcomes at all temporal and spatial scales; (2) develop new products and technologies, such as integrated surveillance and early warning systems; (3) monitor and evaluate the effectiveness of modifications to current policies and programs that take climate change into account; (4) strengthen capacity building, including training, for the public, health care providers, and researchers; and (5) address the climate change-related vulnerabilities of health care facilities.

An example of a research need comes from the first generation of adaptation projects in Senegal and other LMICs to integrate climate change adaptation into development policies.¹¹⁵ These projects were implemented to respond to threats to livelihoods in major sectors (e.g., agriculture, fishing, forestry) with the support of multiple donors and multilateral funding agencies (e.g., UNFCC, UNDP, USAID, World Bank, GEF, and Adaptation Fund). Because these projects generally did not include a health component, not much is known about the health benefits of the projects. Estimating the health benefits of adaptation projects in other sectors or adding complementary health components could build essential cross-sectoral collaborations, bring a more human face to ecosystem-based adaptation projects, increase public and decision-maker supports for such projects, and increase the appeal of the project.

Advocacy For Health Adaptation

Health sector officials, within and outside of government, have begun to recognize climate change to be an urgent threat to health and well-being. Major health and social organizations and international authorities such as the Global Climate and Health Alliance, the Climate and Clean Air Coalition, the World Medical Association, Health Care Without Harm, the Global Alliance for Clean Cookstoves, and WHO have called for greater actions to address population health risks from climate change, including by

reducing greenhouse gas emissions. At the 2018 Global Climate and Health Forum, 50 health organizations representing millions of health professionals and thousands of hospitals worldwide adopted a climate change and health call to action.¹¹⁶

Vision For The Future

The vision for health adaptation is climate-resilient health systems:¹¹⁷

...to enhance the capacity of health systems to protect and improve population health in an unstable and changing climate. Ultimately, health systems should be increasingly strengthened and continue to be efficient and responsive to improve health, reduce inequities and vulnerability, and provide adequate social and financial protection, in light of the shocks and stresses they may face from climate variability and change.

Achieving that vision requires innovation and investment. Investments in health adaptation are negligible despite the evidence of harm and despite health being a priority in many national climate change planning documents. There are no estimates of the needed magnitude of investment, but general figures could be estimated from investments in other health challenges and from estimates of the costs of adaptation.

Antimicrobial resistance (AMR) is a serious international problem.¹¹⁸ AMR is projected to result over 40 years in the loss of US\$3.9 trillion.¹¹⁹ Investments in research by the United States National Institutes of Health (NIH) in AMR in 2018 was \$522 million for approximately 150 projects¹²⁰; the UK has over 1500 active projects¹²¹. From 2007-2013, the European Union and national European governments funded 1,243 AMR research projects for a total investment of €1.3 billion.¹²² AMR also may be associated with climate change because resistance increases with temperature.¹²³

In contrast, the NIH funded \$17 million in research projects and meeting support on climate change and global warming in 2018 (only 3% of the total for AMR). Reviews on climate change and health funding in European Union and Australia found smaller investments.^{124,125}

Funding is needed not just for research but also for adaptation implementation, monitoring, and evaluation, and for increasing the climate resilience of healthcare infrastructure.

Estimates of the costs of adaptation, based on the additional costs to treat climate-sensitive health outcomes, range from a few to tens of billions of dollars annually, with one study estimating that these included only 30-50% of the extra health burden of climate change.¹²⁶

Any vision for the future must be based on efforts by national governments, international organizations and funders, bilateral donors, and others investing in research and development, and in adaptation funding, implementation, monitoring, and evaluation, to build climate resilience in health systems at all scales.

While incrementally mainstreaming climate change into policies and programs for climate-sensitive health outcomes is critical, that will likely be insufficient to manage increased hazards from climate change, in the context of other global changes, demographic shifts, socioeconomic development, and efforts to achieve the Sustainable Development Goals. The World in 2050 (TWI2050) identified transformations that would promote achieving all 17 SDGs, including achieving access to nutritional food and clean water for all while protecting the biosphere and the oceans, and science, technology, and innovations to support sustainable development.¹²⁷

Health adaptation efforts that complement innovations and investment in each of these SDG-related transformations would significantly improve population health, no matter the extent of climate change. Two examples are increasing the use of climate data and information, and using innovation and technology to advance health adaptation.

Climate Data And Information

In many countries, partnerships exist among health sector officials, meteorologists, climatologists, and emergency managers to employ health, weather, and climate data to reduce risks from existing climate hazards and future threats. Health authorities face challenges in utilizing weather and climate data because of a lack of expertise that affects the ability to access, analyze, understand, and use climate-related information in health adaptation programs. As the world continues to warm and climate change impacts increase, greater collaboration will be needed to develop and deploy new technologies, tools, and analyses that can address emerging climate hazards; complex health risks (e.g., impacts on mental health, impacts

from cascading or cumulative events); and challenges of effective risk communication.¹²⁸

Health authorities should take advantage of further opportunities to employ environment data to reduce climate-sensitive health outcomes.^{129,130} The Global Framework for Climate Services is supporting the development of a range of weather and climate services including hazard maps, severe weather forecasts (e.g., extreme heat events, violent storms, floods, droughts, and air pollution episodes) and projections of future climate change relevant for protecting health and well-being.¹³¹ Projects applying climate data and information to protect health include an early warning system to inform infectious diseases control in Europe, employing climate information to predict and control meningitis epidemics in West Africa, development of climate-specific pollen indicators and monitoring tools in Hungary, and an integrated real-time early warning system for heat, cold, floods, forest fires, storms, and smog in Quebec, Canada.

Innovation And Technology

Rapid advances in innovative technologies offer opportunities to advance health adaptation initiatives that protect populations from climate change impacts. Drone deliveries of essential equipment and medicines can facilitate disaster relief, as well as enhancing search and rescue efforts, assessing damage and mapping disaster zones.¹³² Digitizing medical records could increase the length of data series to inform development of early warning systems. E-health or telemedicine has the potential to increase access to health services and the speed of communications in remote regions. For example, automated phone warnings to vulnerable people during high heat episodes decrease health service use by 50%.¹³³ New communications technologies have expanded the scope of ways to communicate with the public on climate change issues and to assist in adaptation, for example through weather alerts. Smartphones and social media platforms have expanded available official, less official, and unofficial channels of communication (e.g., government social media accounts; opt-in short message service (SMS)-based alerting systems; third party weather applications on personal devices; eyewitness accounts of extreme weather). Private companies such as Google and Facebook are applying their user data to provide alerting services that may contribute to general efforts to increase disaster preparedness.¹³⁴ Public

health is catching up on using big data, machine learning, and AI to improve population health. For example, big data on air passenger volume from international areas with active chikungunya transmission, twitter data, and vectorial capacity estimates of *Aedes albopictus* mosquitoes can help identify virus dispersion from an outbreak, providing more timely information than other indicators such as searches of google trends, to better control outbreaks.¹³⁵

The extended timeframe associated with climate change impacts necessitates a broader scope for risk assessment and risk reduction efforts. As time horizons for key decisions are extended, other dynamics outside the health sector become more important to consider. Vulnerabilities will shift because of changes in climate as well as migration, urban form, technology, access to safe water, access to improved sanitation, and factors associated with development choices.^{136,137,138} Further, new evidence and knowledge on trends and projections of climate and vulnerability, and best practices in adaptation, will inform development of new or modification of current options for managing health risks. Together, these changes are likely to alter the effectiveness and success of health systems' strategies and policies, such as mental health services to respond to increases in the frequency and intensity of extreme weather and climate events; these alterations are important to consider in risk reduction planning.

Examples

Bhutan

The Health National Adaptation Plan identifies needs and opportunities for mitigation and adaptation actions to prepare for and respond to the health risks of climate change. H-NAP focus areas include: (1) vectorborne diseases, (2) water, sanitation, and hygiene, (3) food security, (4) capacity development and research, and (5) climate and health financing.

Climate change risks in Bhutan are projected to include a warmer and wetter climate, and more frequent extreme weather events, including flash floods, landslides, and windstorms. A project to pilot integrated surveillance for climate-sensitive diseases in Bhutan was funded by the Special Climate Change Fund. The aim of the project was to monitor the risk factors (climate factors) along with the collection of routine epidemiological surveillance data for climate-sensitive diseases. Six adaptation activities

focused on integrated surveillance were piloted, building on collaborations between the Ministry of Health and the Department of Hydro-Met Services. Data were collected for diarrhoea, acute respiratory illnesses, malaria, dengue, Japanese encephalitis, Kala-azar, and dysentery. In the long term, the aim is to develop forecast models, issue risk warnings, and develop response plans.

The project largely depends upon the work of the Health Assistant at each participating Basic Health Unit (BHU), who collects daily rainfall, humidity, and maximum and minimum temperatures using the weather station situated at the BHU. The health data are sent monthly in excel format to the Department of Public Health and the paper-based meteorological data are sent to the Department of Hydrology and Meteorology, at the national level.

Staff reported that this activity of measuring the meteorological data and collecting the health data in another form (alongside the standard health information system) does not add significantly to their workload. Staff also learnt the importance of the weather data, and the potential for health workers to use the correlations to identify vulnerable groups. Further support for these types of adaptation initiatives will help equip health services to understand and respond to the health risks of climate change.

Bhutan is a useful country example to learn from because the health sector has been comprehensively represented in the National Adaptation Planning Process, with the

recognition that excluding the health sector in adaptation planning can result in programs and policies in other sectors that negatively affect population health, as well as the potential to miss opportunities for critical action to protect population health.¹³⁹

Canada

Based on assessments and reviews over the past 10 years, the expected health risks of climate change include, among other issues, increased emergence and re-emergence of infectious diseases from three sources: northward spread from the United States by human-mediated introduction or range expansion facilitated by movement of pathogens and vectors by wild animals; human-mediated introduction from elsewhere in the world; and re-emergence/epidemics of endemic diseases.

The climate-sensitive diseases posing the most immediate threat are vectorborne diseases, including exotic mosquito-borne diseases for which humans are the main reservoirs (e.g. malaria, dengue); and Canada-endemic mosquito-borne diseases (e.g., West Nile virus [WNV]) and tick-borne diseases (e.g., Lyme disease). Those endemic to Canada and neighboring parts of North America are zoonoses (diseases transmitted from animals to humans) for which the reservoirs are wildlife. Climate change is anticipated to facilitate emergence and re-emergence of these diseases by increasing the climatic suitability (particularly in terms of temperature) of Canada for their growth and reproduction, increasing the abundance of pathogens and vectors in other countries, and causing climate variability and extreme weather events that may result in epidemics of Canada-endemic mosquito-borne diseases such as WNV infection (Figure 5).¹⁴⁰

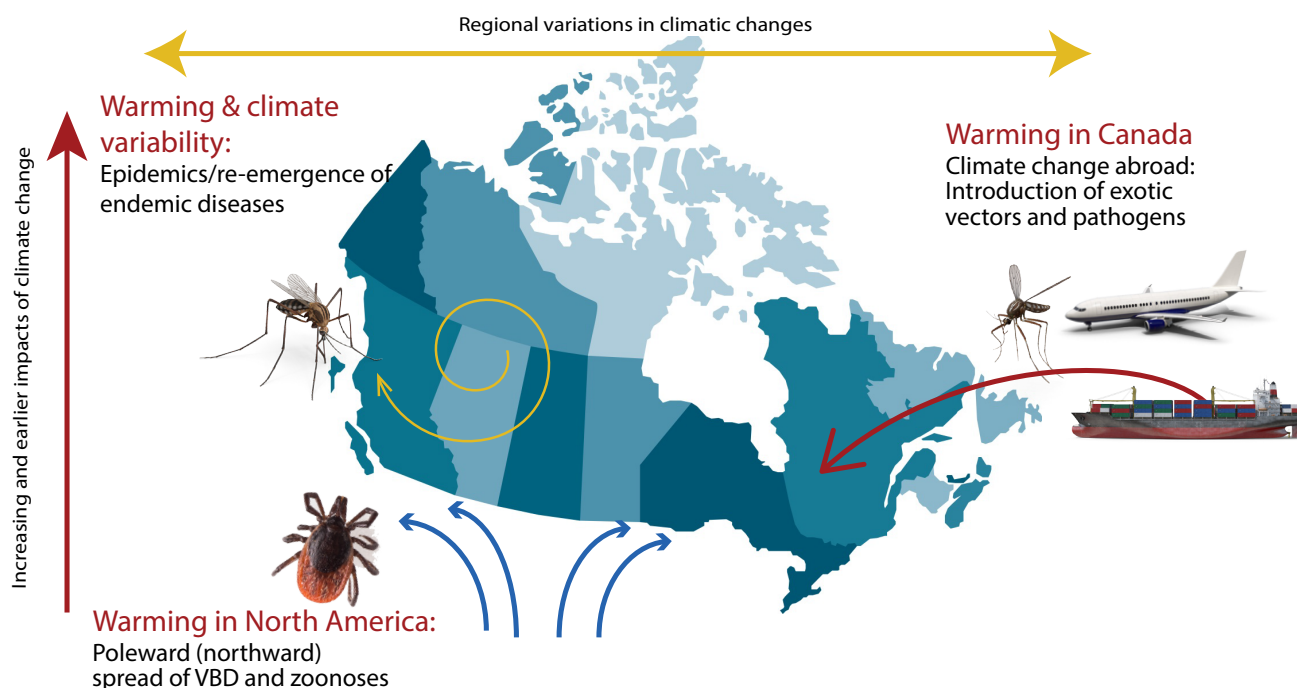
In recent decades, Canada experienced vectorborne disease emergence associated with invasion from outside North America (the invasion of WNV, likely from the Middle East) and south-to-north invasion of vectorborne diseases from the United States (Lyme and other tick-borne diseases and the mosquito-borne Eastern Equine Encephalitis). The change in the geographic range of Lyme disease is attributed to climate change.¹⁴² While not certain, it is possible that the other vectorborne disease emergence/re-emergence events also were associated with effects of climate change.^{143,144,145} WNV occurs as epidemics that are likely driven by weather events.^{146,147} The emergence of chikungunya and Zika virus in the Americas, including

Health worker collecting and measuring rainfall data at BHU (photo K. Bowen).

FIGURE 4



FIGURE 5



popular holiday destinations for Canadians, has focused public health attention on the possible consequences of climate change-driven emergence of infectious diseases outside Canada.

As in many other countries, there are two streams of public health activities in the context of emerging infectious diseases: upstream preparedness and outbreak response. Within these are three key public health activities: risk assessments to identify current and future risks; surveillance for known or possible risks; and interventions to prevent and control. In response to climate change driving emerging vectorborne disease threats (as well as impacts on food- and waterborne disease), the Public Health Agency of Canada (PHAC) developed programs to enhance capacity to respond to increasing threats (<https://www.canada.ca/en/health-canada/services/climate-change-health.html>) by investing in risk assessments;¹⁴⁸ surveillance;^{149,150} tools to support local efforts to adapt (e.g., systematic reviews of methods)¹⁵¹; and disease forecasting.¹⁵²

Methods used for surveillance of endemic and emerging infectious diseases include following trends in incidence, and identifying the spatiotemporal distribution and spread of cases nationally (National Notifiable Disease

Surveillance System (NNDSS); <http://diseases.canada.ca/notifiable/>) and at Provincial/Territorial levels using “One Health” surveillance for infection in sentinel animals and disease vectors as well as for human cases.¹⁵³ Targeted enhanced surveillance systems are capable of identifying risk factors in the affected population¹⁵⁴ and disease clusters.¹⁵⁵ Syndromic surveillance is another method of capturing information on possible cases during disease emergence events, e.g., the use of data from pharmacies on flu remedy sales to track the evolution of H1N1 influenza in Canada.¹⁵⁶

A key capacity is to identify and treat cases of disease. Diagnosis and treatment of cases reduces transmission and contributes to controlling outbreaks. However, this requires vigilance by frontline health care workers. In some outbreaks, health care facilities can become a focus for transmission, such as occurred during the SARS outbreak in Canada.¹⁵⁷ Increasing antimicrobial and antiviral drug resistance challenges the capacity of health care systems to treat emerging diseases.¹⁵⁸

Despite robust health and public health systems, climate change poses challenges to Canada’s capacity to protect population health.¹⁵⁹ These challenges include the multitude

of possible merging disease risks that stretch the capacity to undertake risk assessments (there is a paucity of data on many identified disease risks),¹⁶⁰ surveillance (which currently focuses on one-disease-at-a-time diagnosis/detection and reporting), and response (particularly in the light of increasing antimicrobial and insecticide resistance globally).

Senegal

Senegal has 700 km of coastline that includes 60% of the population and most of the country's urban sites and economic activities. Senegal includes one of the world's most productive fishing waters, but fishing production is in decline due to global change.¹⁶¹ The communities in the Saloum Islands are a good example of vulnerable groups facing threats posed by the consequences of climate change, including coastal erosion, floods, and declining productivity of the mangrove stands. The Adaptation Fund (AF) is supporting a 4-year adaptation project starting in 2018 that seeks to increase the resilience of the affected communities.¹⁶² The Dionewar AF project focuses on ecosystem-based adaptation (e.g., reforestation of the mangrove), community-based adaptation (e.g., infrastructure against floods, improvement of fish and oyster farming productions) and institutional adaptation (e.g., adaptive communal development plan). Specific actions, such as developing improved fish and oyster farming production systems; conducting training sessions for women's economic activity groups; and modifying the Communal Development Plan to incorporate climate change will likely improve population health. However, the project does not include an assessment of health benefits and trade-offs. Including health in coastal adaptation plans in Senegal is important for building resilience and can provide an example for other coastal communities in Africa.

Because the impacts of climate change in Africa will be felt largely in communities,¹⁶³ reducing rural vulnerabilities is high priority. These activities should be linked to relevant integrated and multi-sectorial policy dynamics at all levels of administration.

Preparing Health Facilities for Climate Change Impacts

Climate change is recognized as an important threat to health facilities and services in Canada. Recent experience

with hazardous events such as wildfires, droughts, heat-waves, storms and floods has resulted in significant disruptions to patient services, and closure of some facilities.¹⁶⁴ Health authorities are beginning to use new tools and information to assess risks of climate change impacts on facilities infrastructures and operations to protect patients, staff and the broader community when hazards strike.

As part of efforts to prepare for climate change impacts on the Nanaimo Regional General Hospital in British Columbia, officials from Island Health Authority and from the facility took a leadership role to examine the vulnerability of key infrastructure using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) risk assessment protocol.¹⁶⁵ The following activities were undertaken as part of the assessment:

- Facility infrastructures were categorized into engineering disciplines: civil, electrical, enclosure, mechanical, structural and water systems;
- Analysis was conducted of the probability of infrastructure failure based upon climate projections related to temperature, rainfall, humidity, water shortages, air pollution from forest fires, and storms obtained from the Pacific Climate Impacts Consortium;
- Consultations were undertaken with clinical and facilities staff to investigate the possible severity of impacts on hospital operations that could affect patient services; and
- A final risk score for the different types of infrastructures was calculated.

Analysis revealed that infrastructures that are at higher risk of future impacts from climate change include water, medical gas, critical air, ventilation, cooling, and heating. Health authority officials are now using this information to guide future hospital retrofits and construction of new buildings. For Island Health Authority, next steps include the following actions aligned with capital asset renewal plans to make health facilities more climate resilient:¹⁶⁶

- Developing strategies to reduce the energy load on the system;
- Increasing cooling capacity for extreme heat events;
- Ensuring emergency potable water supply; and

- Reinstalling return air systems and/or enhanced filtration systems

For other health authorities planning for climate change, the project revealed the importance of (1) ensuring management provides a strong mandate to facilitate broad participation of partners, (2) considering the use of multiple risk assessment tools, (3) giving consideration to infrastructure and operational interdependencies to reduce risks of catastrophic outcomes, and (4) mainstreaming climate-related risk assessment into regular planning activities, including facility expansions, retrofits, and upgrades.¹⁶⁷

Barriers/Enablers/Drivers and Other Cross-Cutting Issues

Governance

The governance mechanisms that support actions to reduce climate change risks to health are challenged by diverse and complex drivers, including vested interests that extend from short to long time scales. National health authorities can play a fundamental role in adaptation by putting it on the agendas of subnational partners, enhancing capacity through legal frameworks and with financial resources, and supporting research and priority setting to direct local actions.¹⁶⁸

An approach that has gained attention and adoption in a number of contexts is Health in All Policies (HiAP).¹⁶⁹ The aim of HiAP is to ensure that health impacts are incorporated into the policy development processes of all sectors and government agencies, ultimately creating an integrated policy response across the whole of government.¹⁷⁰ Governments that have implemented this approach include Finland, other members of the European Union, the state of South Australia, and some Canadian provinces. Key factors for the successful implementation of HiAP include leadership and support from central government, the allocation of dedicated resources, clear timelines, a supportive culture, and the articulation of outcomes.¹⁷¹ These key factors for the successful implementation of HiAP are important considerations for developing climate change and health policy, given the similarities of the challenges in terms of cross-cutting characteristics¹⁷² but also in terms of the importance of obtaining broader buy-in at a high policy and political level.

At the international level, greater involvement of the health sector in UNFCCC adaptation processes (for example by including a health representative in the UNFCCC country delegations) could increase the prioritization and implementation of health activities in National Adaptation Plans.

Effective health adaptation planning requires cross-sectoral collaboration with decision makers outside of the health sector (e.g., infrastructure, transportation, energy, water and sanitation, urban planning, agriculture, conservation), coordination of actions across governance scales, and strong national adaptation planning that is linked to subnational actions.^{173,174} Health authorities need to collaborate closely with partners to assess the health benefits and risks of sectoral adaptation or greenhouse gas mitigation activities to inform policy and program development.^{175,176} Deleterious impacts on health can result in the absence of this collaboration.

Capacity Constraints

There are large capacity constraints within the health sector that are limiting appropriate and effective responses to climate change. These constraints are not just financial, but are also related to absorptive capacity, technical capacity, and capacity to engage with high level political processes. Absorptive capacity and technical capacity are sometimes linked and exist at sub-national and national levels. These capacity issues can arise when there is a substantial increase in the level of funding for climate change programs in the context of insufficient staff and other resources to appropriately absorb this funding and carry out the needed activities. In addition, LMICs generally face the challenge of continually relying on international technical advice for their country-level programs to progress their climate and health activities. This is obviously necessary in some cases but indicates the importance of investing in a rapid and rigorous scale-up of capacity development initiatives to help ensure countries can shift towards approaches that use local expertise and build on local skills and knowledge.

The capacity of the health sector to influence high-level climate change policy-making is limited for multiple reasons. In many countries, the ministry of the environment is viewed as responsible for environmental issues, including by the ministry of health. The health sector often views itself as tangential to environmental issues such as climate change, leaving health adaptation without a champion.

Magnifying this problem is that many health ministries are in the early stages of incorporating a comprehensive and systems-based understanding of climate change and health. Opportunities to strengthen the health sector's role in policy-making include initiatives such as: (1) including a health representative in the UNFCCC delegations; (2) encouraging secondments between the health and environment ministries; and (3) promoting the resources currently available for advocacy purposes, such as the WHO's Health and Climate Change Country Profiles.¹⁷⁷

Although health systems have a long history of monitoring and evaluating interventions to determine effectiveness, there is limited experience with these processes in the context of climate change. As opposed to other sectors, there is less risk of lock-in because most health adaptation options are easily modifiable over time (e.g., surveillance systems).

Capacity constraints also arise from societal (e.g. equity, customs, values, and traditions), governance effectiveness, and other factors. There also are barriers and constraints outside the health system that will be important, such as the extent to which climate change affects ecosystem services.

Conclusions

Climate change is adversely affecting population health and health systems today, with additional climate change projected to substantially increase the burden of climate-sensitive health outcomes and the damage to healthcare facilities if sufficient mitigation and adaptation actions are not taken. The population health risks of climate change are generally known, with baskets of technologies, policies, and programs available to reduce their burden of disease. The significant burden of some climate-sensitive health outcomes, such as undernutrition, malaria, and diarrheal disease, indicates that further investments are needed.

Climate change, as a stress multiplier, will interact with and, in many cases, exacerbate health burdens. Further, many health care and public health facilities are situated in locations vulnerable to storms, floods, and other extreme weather and climate events, putting healthcare workers and the populations they serve at additional risk. Regardless of how fully mitigation is pursued, adaptation is critical to protect and promote population health.

Investments in adaptation help ensure healthy individuals and communities to underpin achievement of the Sustainable Development Goals. The growing numbers of health adaptation projects are providing insights and lessons learned to inform scaling up and out but are manifestly inadequate to meet the demonstrated need for widespread adaptation activity and to develop the needed expertise to facilitate climate change adaptation in the health sector.

Recommendation 1: Raise national investments in climate change and health research to more than 1% of health and social services research budgets in high-income countries and 5% in middle-income countries, and investments in health adaptation for population health and health system resilience to at least 5% of multilateral, bilateral, and donor adaptation funding for LMICs. Further, national or international support should be provided for countries to include a health representative in their UNFCCC delegation, to strengthen high-level awareness, advocacy, and action.

Research investment can (1) build the knowledge base of how changing weather patterns and extreme events affect morbidity and mortality; (2) develop more complex and finer scale models of the magnitude and pattern of future health risks under a range of climate and development scenarios at national and subnational scales, quantifying the separate and combined contributions of climate change, demographic change, urbanization, and other socioeconomic drivers to adverse health outcomes; (3) identify, monitor, and evaluate adaptation policies, and processes for effective and efficient implementation, including stress testing for robustness of infrastructure and management planning; and (4) build courses and university/college-based programs to train the next generation of population health and health care workers/providers, thus building a climate-ready workforce. Centers of excellence are needed in all regions, with long-term funding to support research and training. Funding for fellowships and student exchanges across countries would catalyze research discovery and uptake.

Investment in health adaptation can: (1) increase climate-resilience in all components of health systems; (2) identify lessons learnt and best practices for scaling up and out; (3) support coordination and knowledge exchange across countries and regions; and (4) begin addressing some of the urgent and immediate needs to climate-proof

health system infrastructure. Further investments will be needed when major improvements are needed because of climate change (e.g., reorganizing healthcare facilities to manage heatwaves and other extreme events) and to move facilities threatened by storms, floods, and sea level rise.

Recommendation 2: Develop and fund scenario-based, integrated adaptation plans within health systems and across sectors that account for the multiple and interacting risks of climate variability and change on all aspects of human and natural systems. This involves (1) mainstreaming climate change environmental impacts and scenarios of social impacts into all relevant health policies and programs; (2) mainstreaming health into all climate change-relevant policies (e.g., Health in All Policies); (3) developing systems-based adaptation approaches within a region, explicitly exploring and managing possible synergies and trade-offs across sectors, and taking into account risks outside recent experience; and (4) attending explicitly to infrastructure adaptation needs when such infrastructure is essential to population health.

Current policies and programs to manage climate-sensitive health outcomes implicitly assume a stationary climate. They need to be modified to explicitly consider how changing weather patterns could affect the geographic range, seasonality, and intensity of transmission of climate-sensitive health outcomes, and to explicitly consider iterative risk management approaches that incorporate uncertainties in the rate of climate change and uncertainties in development choices and their consequences. Progress is underway through conducting vulnerability and adaptation assessments and through developing the health component of national and regional adaptation plans, with many more countries seeking funding for external technical and financial support to begin the process.

Stress testing is an approach to extending vulnerability and adaptation assessments to explore the potential health risks of climate change far outside the range of recent experience with extreme weather events and other climate-related hazards.¹⁷⁸ Climate and health stress tests are designed to increase the capacity of health systems and related sectors to manage potentially disruptive climate-related shocks and stresses. The stress test explores approaches to effectively manage acute and chronic climate-related events and conditions that could

directly impact health systems, and climate-related events in non-health sectors that can indirectly impact health outcomes and/or health system function. The results of the stress tests could be incorporated into national preparedness scenarios.

As mentioned under Recommendation 1, regular evaluation is needed of modified policies and programs to determine their effectiveness as the climate and other drivers of health outcomes change, and to identify when additional modifications are needed to keep pace with climate variability and change.

Because many of the drivers of the health risks of climate change arise from other sectors, health needs to be explicitly considered in adaptation policies and programs in sectors such as water, agriculture, and development, and into adaptation planning for cities. For example, city planning may need to be modified to account for worsening of extreme weather and climate events, leading to more potent storms, coastal erosion, flooding, and heatwaves, within the context of increasing energy-efficiency and decreasing greenhouse gas emissions.

Adaptation needs to be optimized within regions to balance synergies and trade-offs across sectors. Policies and actions in one sector can result in harms or dis-benefits in other sectors, so explicit consideration is needed of how to manage competing needs and desires. Strong stakeholder engagement, including with the public, is needed to ensure support for choices made. For example, increasing demand for water from growing populations will need to be balanced with needs for agriculture, industry, and enjoyment, ensuring water safety and security even as water availability changes. Achieving the SDGs and Sendai Framework for Disaster Risk Reduction would substantially contribute to increasing health systems resilience.

Recommendation 3: Enhance the capacity for aggressive adaptation actions. Innovative and participatory mechanisms and fora should be developed to facilitate the uptake of research findings into policies and practice. This includes designing adaptation projects to efficiently identify lessons learned and best practices so they can be shared more readily across regions and sectors. Ensuring stakeholder engagement throughout developing, implementing, monitoring, and evaluating health adaptation projects can increase effective uptake; this should include engagement with highly vulnerable communities and populations that

can empower and build capacity for action at the community level, such as Indigenous populations and youth. Consideration for social and health equity should be included in the design, implementation and monitoring of adaptation measures to identify and resolve barriers to adaptation and ensure that existing inequities and inequalities are not inadvertently advanced.

In some countries, increasing decentralized health systems means that additional funding may be necessary for local health authorities to engage in research and adaptation uptake.

Recommendation 4: Develop new technologies for health adaptation. In addition to increasing the implementation of adaptation measures, new technologies and tools will be needed to protect and promote health in a changing climate, and to address concerns about, for example, declining worker productivity with higher temperatures, increases in the geographic range of vectorborne diseases, and increases in undernutrition because of changes in the nutritional quality of key cereal crops. A few suggestions include sensors in clothing may be able to detect when workers are beginning to develop heat stress; new materials for playground equipment to protect children from touching too-hot surfaces; environmental sensors to be used in conjunction with early warning and response systems to warn of impending outbreaks of vectorborne and

waterborne diseases; and using artificial intelligence and big data to better understand and forecast disease patterns. There are large numbers of possibilities that could be developed through investments in new technologies for managing the risks of climate-sensitive health outcomes.

At the same time, investments are needed to ensure that technologies developed for adaptation in other sectors do not inadvertently harm population health.

Recommendation 5: Promote the development of zero emission technologies and in the future; and that facilitate technology transfer to LMICs.

Air pollution kills more than 7 million people annually, so developing zero emission technologies to reduce indoor and outdoor air pollution emissions from power plants and from transportation would reduce the level of adaptation needed. There are multiple technologies available that can be deployed now.

Further, climate change mitigation policies for air quality, transportation, and diet provide significant, nearer term, local ancillary health benefits that could offset a substantial proportion of their costs.¹⁷⁹ Because mitigation policies also have the potential to cause health harms, robust research is needed to guide climate policy-making; effective mitigation may not optimize health outcomes.

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ABOUT AUTHOR'S RESEARCH INSTITUTION

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