Global Health

Climate Change
Impacts on and Implications for Global Health

Michael E. St. Louis, MD, Jeremy J. Hess, MD, MPH

Abstract:
The most severe consequences of climate change will accrue to the poorest people in the poorest countries, despite their own negligible contribution to greenhouse gas emissions. In recent years, global health efforts in those same countries have grown dramatically. However, the emerging scientific consensus about climate change has not yet had much influence on the routine practice and strategies of global health. We review here the anticipated types and global distribution of health impacts of climate change, discuss relevant aspects of current global interventions for health in low-income countries, and consider potential elements of a framework for appropriately and efficiently mainstreaming global climate change–mitigation and –adaptation strategies into the ongoing enterprise of global health. We propose a collaborative learning initiative involving four areas: (1) increased awareness among current global health practitioners of climate change and its potential impacts for the most disadvantaged, (2) strengthening of the evidence base, (3) incorporation now of climate change–mitigation and –adaptation concerns into design of ongoing global health programs, and (4) alignment of current global health program targets and methods with larger frameworks for climate change and sustainable development. The great vulnerability to climate change of populations reached by current global health efforts should prompt all concerned with global health to take a leading role in advocating for climate change mitigation in their own countries.

Introduction

By 2008, scientific consensus has been largely reached: Human activity is causing the atmospheric accumulation of greenhouse gases, increasing temperatures, and causing changes in the hydrologic cycle.1,2 These climatologic effects, in turn, contribute to a wide array of health effects,3–9 including the direct effects of temperature and climatologic instability, such as heatwaves, drought, and increased frequency and severity of extreme precipitation events.10 Secondary or “systems effects” are also included, such as those from positive or negative impacts on agriculture, clean water access, shifting geographic distributions of infectious diseases, migration, increased competition for scarce resources, and the potential for armed conflict.5,6,8–20

The health impacts of climate change will not be distributed uniformly,21 and the distribution of the most severe health burdens is almost inverse to the global distribution of greenhouse gas emissions.22 The accumulated reservoir of greenhouse gas emissions overwhelmingly originates from wealthy, industrialized countries in temperate climates, whereas predicted health effects are highly concentrated in poor countries that typically already suffer the worst health (Figures 1 and 223–25). The profound health inequities that climate change creates for the world’s poorest citizens present a special challenge to those concerned with global health.22,26,27

On the other hand, the global health community also confronts immediate global health challenges represented by preventable, treatable, and remediable diseases that kill millions each year.28–30 Although resources for global health have increased dramatically in recent years, substantial shortfalls remain in meeting even the most basic and cost-effective needs.31 The urgency of existing global health needs has led some to argue against diversion of resources and attention to the more distant global health impacts of climate change.32 This is ill-advised, as the health effects of climate change are increasingly manifest and may have a devastating effect on global health in the next several decades. Moreover, there are important potential co-benefits for global health in recognizing climate–health associations, considering sustainability in global health programming, and developing a coherent, concerted strategy for addressing climate change in global health activities.22,33–37 A near-term plan of

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action to mainstream what we are learning about climate change into existing global health efforts is yet to be formulated.

**Current Risk Factors for Health in Poor Countries**

Health outcomes are, of course, decidedly worse in poor countries, but, equally relevant to the health implications of climate change, the most important risk factors for death and disability in poor countries differ strikingly from those in the developed world (Table 1). Importantly, the leading health risks in the poorest countries—undernutrition, inadequate and unsafe water, poor-quality nutrients, and the burning of low-quality fuels for household use—all exhibit significant climate sensitivity, perhaps even more so than the leading risk factors for death in industrialized countries (Table 1). The mortality burden from undernutrition—25,000 deaths per day, including one child every 5 seconds—is only a small portion of the population that experiences morbidity from hunger and nutritional deficits. Almost 2 million deaths a year, mostly in young children, are caused by diarrheal diseases largely attributable to unsafe water and lack of basic sanitation. Risk has become increasingly concentrated in the world’s “bottom billion,” who have been left behind in the widespread economic growth of the past decades.

It is important to recognize that even the modest climate change observed by the end of the 1990s is already an appreciable risk factor for poor health outcomes in poor countries. Much concern appropriately was generated by the estimates of 22,000 to as many as 70,000 European deaths associated with 2003 heatwaves, but as early as 2000 the WHO estimated that approximately 2.4% of worldwide diarrheal disease...
was attributable to climate change, 6% of malaria in some middle-income countries, and 7% of dengue fever in some industrialized countries. Globally, the mortality attributable to climate change that had already occurred was estimated at 154,000 (0.3%) deaths per year, and the annual attributable burden was 5.5 million (0.4%) disability-adjusted life years (DALYs), with the greatest proportional burden in sub-Saharan Africa and South Asia. It is important to recognize the highly conservative approach WHO uses to estimate these health burdens, as the actual burden is likely much greater.

Climate Change and Global Health Outcomes

Current global health efforts are focused heavily on infectious diseases, maternal and child health, and family planning; increasingly, urbanization and megacities are also the focus of global health activities. At first glance, many global health activities may seem to focus on diseases and processes that exhibit little climate sensitivity, and climate effects have not been at the forefront of research into global health outcomes. Yet many of the most pressing global health concerns are affected directly or indirectly by climate variability and change. Additionally, important system interactions among development, energy, and economic policy all will be shaped by the larger climate change response.

Although the UN Intergovernmental Panel on Climate Change (IPCC)’s Fourth Assessment Report (FAR)1 continues to acknowledge the important lack of certainty of the health effects of climate change, given the precautionary principle and the razor-thin margin on which the world’s poor live, it is important to engage in preventive action that may mitigate future health effects. Table 2 represents the projected major health impacts of climate change for poor countries from the recent IPCC FAR, including malnutrition, arthropod vectorborne disease, morbidity and mortality from extreme weather events and diarrheal disease, and conflict over scarce resources. These and other climate-sensitive global health outcomes, particularly those related to conflict, displacement, cities and urban populations in the developing world, and synergistic effects, are discussed below.

Malnutrition

Climate change poses many nutritional risks to poor populations, and the IPCC FAR concluded with high confidence that climate change will worsen malnutrition in the developing world. Malnutrition already exerts a significant burden on the world’s poor, and 820 million people were hungry in 2002. The burden of malnutrition is already strikingly high in the poorest countries in particular, contributing to as much as 11% of the total global burden of disease and 35% of excess child mortality. In such a context, large numbers of people subsist with limited margins. Climate change is likely to erode these margins for many of the world’s hungry. Whereas climate change may increase agricultural productivity in temperate climates, in low latitudes and areas with marginal rainfall, local warming of even a degree or less may reduce

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<tr>
<th>Table 1. Leading risk factors for total disease burden in 2000 for high-mortality developing countries and high-income countries</th>
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<tr>
<td><strong>High-mortality developing countries</strong></td>
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<tr>
<td>Risk factor</td>
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<tr>
<td>Underweight</td>
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<tr>
<td>Unsafe sex</td>
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<td>Unsafe water, sanitation, hygiene</td>
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<tr>
<td>Indoor smoke from solid fuels</td>
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<tr>
<td>Zinc deficiency</td>
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<td>Iron deficiency</td>
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<td>Vitamin A deficiency</td>
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<td>High blood pressure</td>
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<td>Tobacco</td>
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<td>Cholesterol</td>
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<td><strong>Source:</strong> WHO40</td>
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<th>Table 2. Projected major health impacts of climate change in low-income countries</th>
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<td><strong>Health effect</strong></td>
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<td>Increase in malnutrition and consequent disorders, including child growth and development</td>
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<td>Increase in death, disease, and injury from heatwaves, floods, storms, fire, and drought</td>
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<tr>
<td>Mixed effects on malaria, with some contractions balanced by expanded geographic range and change in seasonality</td>
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<tr>
<td>Change in the range of some vectors of infectious diseases</td>
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<tr>
<td>Increase in diarrheal diseases</td>
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<td>Increase in number of people exposed to dengue fever</td>
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<tr>
<td>Decrease in cereal crop productivity in low latitudes for even small local temperature increases</td>
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Source: IPCC Fourth Assessment Report Climate, 2007
substantially the yield of principal grain crops. Empirical reviews and modeling studies show that climate change is likely to decrease crop yields in the poorest regions of the world, and that the quality of cereal grains is also likely to be compromised as a result of increased climate variability. In addition to its effects on growth and development, malnutrition also puts people at greater risk for a multitude of other infections and compromises global health activities in other areas. For instance, global AIDS and tuberculosis treatment programs are already facing barriers associated with inadequate nutrition, indicating that even modest reductions in food availability and quality can have important negative effects across the spectrum of global health programs.

Other factors related to climate change also may adversely affect food security. Petroleum scarcity will increase fuel prices and drive up the cost of other inputs, such as fertilizer. Carbon taxes or cap-and-trade approaches (which provide economic incentives for reducing greenhouse gas emissions) also will increase fuel prices. Diversion of productive cropland and biomass to biofuels has already contributed to increases in commodity prices. Together, these trends will further compromise food security for the world’s most vulnerable inhabitants.

**Arthropod Vectorborne Disease**

Many vectorborne diseases exhibit climate sensitivity, although a multitude of other factors affect disease range and incidence. The extent to which climate change has already affected the range of certain vectorborne diseases, and to which it is likely to determine future burden of disease from the major vectorborne diseases such as malaria, are subjects of fierce debate, although experts agree that climate is only one of several variables likely to affect future disease incidence. Gage and colleagues discuss vectorborne diseases in a separate paper in this issue so it will bear only brief mention here.

Malaria has the largest worldwide burden of disease of any arthropodborne disease, and even small changes in incidence could have large absolute effects on disease burden. A number of other arthropodborne diseases, such as dengue, leishmaniasis, Chagas disease, and hantavirus exhibit climate sensitivity but have lower prevalence than malaria and less of an absolute disease burden. The IPCC FAR had high confidence in its conclusion that climate change will influence malaria’s epidemiology globally, and less confidence in the findings that dengue epidemiology will be significantly affected. Other recent reviews suggest that dengue’s range and incidence may be changing as a result of climate change, and a consensus has yet to emerge. Review of the literature suggests that populations residing in cooler, higher areas that currently do not support or only intermittently support persistence of malarial vectors are at greatest risk for disease expansion. These populations have not developed resistance to malaria through repeated infection. In other areas, the likely effects of climate change are difficult to anticipate, because declining precipitation and humidity may result in reduced transmission. Although the epidemiology of malaria is highly likely to alter with climate change, a net increase or decrease in malaria cannot be predicted with confidence.

**Extreme Weather**

Climate change will disrupt hydrologic cycles the world over, resulting in more frequent and severe extreme precipitation events as well as more frequent and severe droughts. The IPCC FAR expressed a high degree of confidence in these projections. These changes in the hydrologic cycle have different health effects: Extreme precipitation events are associated with flooding, which causes significant morbidity and mortality in poor countries, and this toll may have increased in less-developed countries in recent years. Flooding also compromises health long after floodwaters have receded as a result of population displacement, infrastructure destruction, crop loss, and increased incidence of respiratory and diarrheal diseases. Even in the U.S., Hurricane Katrina precipitated a crisis in maintaining treatment regimens for HIV and tuberculosis; such effects become an increasing threat to current global health programs as those programs involve increasingly more complex medical regimens.

Droughts are major precipitants of hunger and famine, and contribute to complex humanitarian emergencies. Although many famines are the combined result of drought and political mismanagement, they nevertheless cause significant worldwide disease burden.

**Increase in Diarrheal Disease**

Diarrheal disease is already a major cause of child mortality globally, and, for a number of reasons, can be expected to worsen with climate change, via multiple mechanisms including water scarcity, increased ambient temperatures, flooding, and other changes in the hydrologic cycle. Inadequate handwashing and hygiene are key determinants of the fecal contamination of foods and surfaces and of enteric pathogen transmission. More than 2 billion people already have inadequate or unsafe water, and changes in the hydrologic cycle are likely to decrease water security further, facilitating enteric disease transmission. Additionally, higher ambient temperatures contribute to bacterial growth in food contaminated after cooking. Flood ing often precipitates or aggravates outbreaks of
Potential Conflict-Precipitated Health Effects

Civil conflict can have extraordinary health impacts that extend far beyond, and penetrate far more deeply than, the direct victims of violence. Although not included in the WHO estimates of different risk factors for health (Table 1), a recent informal estimate of the attributable contribution of violent conflict to premature death placed it as high as fifth among all risk factors. Furthermore, the ancillary effects of civil conflict and violence extend far beyond trauma’s direct effects: the conflict in the Democratic Republic of the Congo (DRC) between 1998 and 2006 contributed to 38,000 excess deaths per month, a mortality rate 40% higher than the rest of sub-Saharan Africa. These deaths were overwhelmingly from easily preventable and treatable conditions and from infrastructure damage, rather than from violence itself. These effects are durable and outlast the violence: Excess mortality has persisted in the DRC at least 3 years after the cessation of the main conflict. Conflicts in Rwanda and Darfur, Sudan may be associated with local climate change combined with population pressures, although this is an area of controversy. Regardless, these and comparable situations of high population density and limited resources are certainly susceptible to climate-related aggravation. The effects are difficult to project, and, although not included in any WHO or IPCC estimates of climate-related effects, have potential for great impact.

Displaced Populations

Related to conflict, the large numbers of people displaced internally or across national borders are highly vulnerable to disease; displaced populations also increase the risk of spreading communicable diseases to new areas. Population displacement, which may be driven by drought, other extreme weather, or conflict, often further strains limited local resources and may itself precipitate further conflict. Displacement also interrupts supply chains and access to therapies for chronic medical conditions. The large number of people now on HIV antiretroviral therapy is one of the great successes of current global health efforts, but large-scale population displacement could lead to far-reaching treatment interruption, threatening not only individual patients but also the emergence of antiretroviral resistance at a population level.

Unhealthy Synergy of Climate-Dependent Factors

Independently, the above factors have grave consequences for global health. In reality, they are mutually reinforcing. Drought exacerbates malnutrition, and causes populations to become displaced, where they can be subject to different patterns of vectorborne diseases and introduce new infectious diseases into previously unaffected areas. Floods precipitate cholera and other diarrheal diseases, can affect infrastructure for years, and can contribute to a biologic context where oral vaccines become less effective. The interaction of these and associated ecologic effects may result in profound and unpredictable impacts associated with quite gradual changes in climate, especially for communities with limited adaptive capacity.

Climate Change, Public Health, and Global Health: Terms and Key Concepts

The UN Framework Convention on Climate Change identified two main strategies for limiting the negative impacts of climate change: mitigation and adaptation (unfccc.int/essential_background/glossary/items/3666.php). Mitigation involves reduced production and/or increased sequestration of greenhouse gases. Adaptation refers to activities that preserve function and health in the face of existing climate change.

From the standard public health perspective of primary, secondary, and tertiary prevention, mitigation is
in fact zero-order prevention, as it focuses on preventing the hazard from coming into being, where primary prevention involves preventing the interaction between the hazard and human hosts. Adaptation includes elements corresponding to each of primary, secondary, and tertiary prevention in public health. Public health has also relied on a separate framework, the ten essential public health services, to highlight important public health activities in the climate change response. In addition, public health practitioners have focused on the concept of co-benefits in discussing adaptive strategies and their effects on human health. Co-benefits are positive health impacts associated with greenhouse gas mitigation interventions, such as increased cardiovascular fitness and decreased respiratory disease prevalence, as a result of increased reliance on human-powered transportation (e.g., walking or bicycling versus driving or using transit).

The mitigation and adaptation landscapes are fundamentally different in rich and poor countries, and this difference has implications for equity and for global health policy. The per capita contribution to global consumption of the very poorest of countries is disproportionately small (Figures 1 and 2), so that, with the exception of a few, specific high-yield opportunities in poor countries that could also have important health co-benefits, the focus on mitigation needs to remain with the leading emitters of greenhouse gases, including both industrialized countries belonging to the Organisation for Economic Co-operation and Development (OECD) and newly industrializing, middle-income countries such as China and India, which have rapidly risen in the ranks of global greenhouse gas emitters. Proportionally, to achieve more equitable per capita emissions levels worldwide, reduction of industrialized countries’ emissions should be significantly greater than that of less developed nations. Middle-income countries with large absolute emissions profiles must also mitigate aggressively to conform with convergence per capita emissions targets, and technology transfer from industrialized to less industrialized countries will be fundamental to facilitating economic growth while constraining emissions.

However, one specific opportunity for health co-benefits from mitigation efforts is particularly instructive for global health. The indoor burning of biomass (especially wood and charcoal) for cooking and heat is a major contributor to greenhouse gas production in low-income countries, and the major source of indoor air pollution, which in turn is a major risk factor for two of the ten leading causes of loss of DALYs in low-income countries (i.e., lower respiratory infections and chronic obstructive pulmonary disease). Current estimates are that biomass fuels in households are responsible for 0.7 to 2.1 million premature deaths annually in low-income countries from a combination of lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer; two thirds occur in children aged ≤5 years and the rest mostly in women. Although combustion of liquid natural gas produces less indoor air pollution, its cost, distribution, and sustainability are concerns. Higher-efficiency ovens for biomass, solar ovens, or other strategies could reduce generation of greenhouse gases, while having a major impact on a leading risk factor for poor health in the poorest countries.

The Practice of Global Health in 2008

Global health resources, actors, and activities have experienced significant expansion recently, and the sector is wrestling with the rapid growth and an increasingly decentralized structure. Apart from poor countries’ own resources, between 2000 and 2005, international aid for health more than doubled, to more than US$12 billion annually. As recently as 2001, two of the most important current leadership organizations in global health—the Bill & Melinda Gates Foundation and the Global Fund for AIDS, TB, and Malaria (GFATM)—did not exist. In 2004, the President’s Emergency Plan for AIDS Relief (PEPFAR) committed to US$15 billion over 5 years for HIV treatment and prevention, the largest single commitment of resources from one government to a specific global health problem. By 2005, in Uganda and Ethiopia, international aid for HIV/AIDS alone had exceeded the governments’ entire budget for all health conditions and efforts. The sharply increased resources have brought progress, but also new challenges and costs. The number of organizations devoted to global health, including public–private partnerships, has mushroomed, each with its specific purpose, operating principles, and operational targets—challenging the overall governance of global health efforts and precipitating calls for new “architecture of global health.”

As with any growing industry, global health is faced with increasing carbon costs and the question of how to service its mission while reducing its greenhouse gas emissions. One group of investigators conservatively estimated that just one of its multicenter, international trials generated 630 tons of CO₂ equivalents, corresponding to about 525 round trip flights from London to New York for one passenger. Far beyond its carbon costs, the increased number of global health organizations imposes transactions costs on senior government officials in poor countries, typically requiring separate situation assessments, proposal development, monitoring and evaluation systems, and other components of modern aid programs. At best, new efforts to address climate change preparedness among the poorest countries face the complex current environment and the limited attention and absorption capacity of national health leaders to take on new health threats. At worst, existing global health programs could view
climate change preparedness efforts as a distraction or competition with their ongoing work.

Promoting Awareness and Action on Climate Change Within Global Health Efforts: A Collaborative Learning Initiative

The burden of the health effects of climate change on the world’s poor should be of great concern for the global health community, particularly given the potentially severe consequences, the inequitable origin of greenhouse gas emissions, and the mitigable nature of many of the worst ill effects. Thoughtful articulation of specific steps for acknowledging and studying the increasing importance of climate–health relationships and incorporating both mitigation and adaptation efforts into global health programming are needed. This articulation is needed at several levels: conceptually in the field as a whole; operationally at the program level; and individually at a personal and professional level for global health scientists, practitioners, and advocates as well. To stimulate broader discussion, we propose four strategies for pursuing both action and collaborative learning exercise to deepen understanding and synergy between the community involved in traditional global health programs and the community involved in global climate change science and policy (Table 3).

Table 3. A short-term program for awareness and action on climate change within the global health community

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<thead>
<tr>
<th>Strategy and examples</th>
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<tbody>
<tr>
<td>1. Maintain and promote mutual awareness of climate change and global health communities, and serve as role models individually and institutionally for associated best practices</td>
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<tr>
<td>Serve as role model for economic and behavioral options common to all people: reduce carbon footprint systematically through changes in areas such as transport and housing</td>
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<tr>
<td>Adopt for personal use and help adapt for diverse settings new estimates for sustainable individual consumption standards for animal protein and red meat (e.g., suggested at 90 gm (3 oz)/day and 50 gm (1.8 oz)/day, respectively)</td>
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<tr>
<td>Consider proposed climate change–related best practice recommendations for clinical trials in global health, and extend similar approaches to other activities of global health</td>
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<td>Disseminate messages based on scientific consensus regarding climate change and health; include dissemination both to and through global health trainees</td>
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<td>Incorporate climate change awareness into the mainstream of other public health and sustainable development programs (as HIV/AIDS programs have been mainstreamed into non–health sectors)</td>
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<tr>
<td>2. Help strengthen the evidence base and accessible information about impacts of climate change on poor and vulnerable populations, and productive responses to those impacts</td>
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<td>Incorporate climate change–sensitive variables in ongoing data collection where feasible and appropriate (e.g., climate and weather variables in research on malnutrition)</td>
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<td>Explicitly assess direct impacts of climate change on program activities (e.g., ambient temperature and protection of vaccine cold chain infrastructure; agriculture productivity and associated nutritional impact on effectiveness of HIV antiretroviral treatment)</td>
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<tr>
<td>Assess health co-benefits of greenhouse gas mitigation efforts (e.g., impact of reduction of indoor smoke on tuberculosis and other respiratory diseases)</td>
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<tr>
<td>Detect and help assure documentation of global climate change impacts in communities where global health practitioners operate</td>
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<tr>
<td>Conduct research to meet strategic gaps in knowledge</td>
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<tr>
<td>3. Incorporate technical approaches and strategies in current global health programs that will facilitate mitigation and adaptation to climate change</td>
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<tr>
<td>Adapt surveillance strategies that allow for early detection of risk factors or health effects related to climate change</td>
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<td>Adopt core laboratory technologies (e.g., real-time polymerase chain reaction) that will provide a more flexible platform for detection of unexpected organisms</td>
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<tr>
<td>Accelerate safe water programs for HIV-affected families to prevent diarrheal disease in AIDS patients, recognizing synergy in promoting adaptation to altered precipitation patterns (and similar specific interventions)</td>
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<tr>
<td>In considering options for microfinance activities and health worker incentives, consider value in terms of mitigation (e.g., efficient stove as incentives for health workers, bicycles for transport) and adaptation</td>
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<tr>
<td>Map vulnerability to anticipated climate change threats along with other health threats, and map community assets to promote general all-hazards resilience as well as to map interventions for current health problems</td>
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<tr>
<td>Incorporate disaster preparedness into all global health operations in poor countries, given the high likelihood of and vulnerability to extreme climate and weather events in those settings</td>
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<tr>
<td>4. Align global health policies and priorities with larger principles and frameworks that support global sustainable development in general, and mitigation of and adaptation to climate change specifically</td>
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<tr>
<td>Articulate and reinforce new constructs or models that mediate more effectively between high-level goals for complex systems (e.g., sustainable development) and critical, shorter-term health goals</td>
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<tr>
<td>Re-commit to and re-energize family planning as fundamental to sustainable development, including both mitigation of and adaptation to climate change</td>
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<tr>
<td>Reinforce and model, through operation of global health program transparency, noncorruption, active community participation and empowerment, and other elements of good governance, to increase the odds of better outcomes in the event of future climate-related shocks.</td>
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1. Promote Mutual Awareness Among Two Vital Communities: Climate Change Science and Global Health

Climate change science has, to date, principally engaged health scientists from the field of environmental health. Unfortunately, environmental health is one of the less well-represented fields in current global health efforts. A first step is for those committed to global health to engage with the emerging science and policy frameworks related to climate change and to become familiar with the public health response to climate change, the potential for co-benefits in mitigation and adaptation efforts, and knowledge and resource gaps. For many, this will require reading and application into the broad and complex field of climate change and its likely health effects. Next, a systematic review of global health activities to discern strategic priorities for addressing climate change in global health is needed. This effort should dovetail with efforts to promote sustainable development, inextricably tied to both mitigation and adaptation efforts.

Sustainable global development is an important concern for global health, and climate adaptation and mitigation are inextricably tied with development efforts. Global health practitioners must concern themselves with this interface. At a minimum, the health sector—global health included—must recognize its contributions to greenhouse gas emissions and the potential for mitigation and adaptation within the sector as a whole and also by individuals. Several prominent leaders in health and science have called for personal efforts to reduce consumption of nonrenewable energy sources for transport and other energy-intensive activities; dietary choices (such as reducing consumption of red meat) associated with reduced global greenhouse gas emissions; and advocacy as citizens for social policies that are likely to reduce climate change–related health impacts globally. Global health practitioners may serve as important role models of such personal choices not only in their own home communities but also in poor countries they visit, where awareness of climate change and health may be less common.

In addition to personal and local institutional mitigation efforts, there may be opportunities to promote adaptation and mitigation strategies as components of health programs in low-income settings. This includes examination of programming to determine where carbon expenditures can be reduced, with an eye toward co-benefits. Global health leaders can incorporate sustainability principles into global health programming, reducing air travel, requiring carbon credits for emissions, and including carbon budgets into major global health activities. On a local level, where many programs subsidize transport of community health workers, provision of good quality bicycles over fossil fuel–dependent transport, when feasible and appropriate, would reduce CO₂ emissions, provide physical activity, and often be more sustainable. Incentives provided to community health workers in tuberculosis control and other programs might include high-efficiency stoves that reduce both carbon emissions and indoor air pollution, simultaneously achieving both mitigation and improved health of workers and their families.

The international research group that recently investigated the carbon footprint of implementing clinical trials in international settings has developed recommendations for best practices for conducting international trials with the least possible negative impact on climate change. Similar assessment processes for carbon-minimizing outcomes could and should be extended to other facets of global health operations.

2. Collaborate to Strengthen the Evidence Base for Climate Effects and Health

Although the monitoring and evaluation programs of a wide range of global health efforts are collecting and analyzing data in most poor countries, internationally based global health programs have greater resources and opportunity to analyze data and make it more broadly available. There is a great need for additional data on the climate sensitivity of important health outcomes, and an urgent need for time-series data sets, including meteorologic data, remotely sensed ecology data, and health outcomes. These parameters may be appropriate to introduce into ongoing global health data collection at low cost, and could yield important new information and lay the groundwork for early warning systems and other interventions. There may be opportunities to investigate the association of climate with disease outcomes, with efficiency of implementing programs, or with the overall health and resilience of communities monitored through the efforts of global health programs. Ongoing global health programs addressing various health conditions often establish infrastructure for research or service delivery that could provide a low– entry cost platform for colleagues from other scientific disciplines to address important research and surveillance issues related to climate change and human health, for which adequate funding may not yet be available.

3. Incorporate Technical Strategies into Global Health Programs that Simultaneously Address or Build Preparedness for the Effects of Climate Change on Health

Global health programs typically have a range of potential technical strategies or interventions that can be addressed to a given need or challenge. The way the challenge is contextualized and the requirements defined for how to meet that challenge determine the choice of technical strategy for addressing the concern.
Considering global health challenges in the context of potentially massive climate–health effects and highlighting the importance of sustainability, mitigation, and adaptation as response parameters would be important steps for increasing global health programming’s sensitivity to climate concerns. For example, disease surveillance efforts can be designed to be sensitive to conditions likely to be particularly affected by climate change, such as malaria or dengue. Laboratory and other technology can be selected with the awareness that vector and disease prevalence may change, and equipment can be chosen to meet the requirement for flexibility to detect such changes as they may occur. Higher priority might be assigned to specific health interventions on the basis that—in addition to their immediate health-promoting effects—they provide more general support to communities for promoting adaptation and resilience to climate change (e.g., point-of-use safe water interventions provided to reduce diarrhea in HIV-affected families). Incentives provided as part of many global health programs, such as to informal and volunteer health workers, could be considered for their potential impact on mitigation and adaptation to climate change. As mentioned earlier, more efficient stoves for indoor cooking may be an especially advantageous incentive, given the importance of biomass burning as a source of greenhouse gases in low-income countries and the major health co-benefits of reducing indoor air pollution. Because community resilience and social capital are defining features of adaptation,27 global health program approaches that map community assets, including various types of social capital, and consciously work to support community social capital and other assets,119 are likely to lead to enhanced capacity to respond effectively to climate change.120,121 Likewise, vulnerability mapping done for other health problems, such as HIV/AIDS,122,123 could plausibly be extended to consider vulnerability to climate-related risks, while at the same time, interventions to increase social capital as a strategy to reduce vulnerability to infectious diseases57,125,124 will likely be generating co-benefits in terms of preparedness for climate change. The increasing predicted frequency of extreme weather events argues for inclusion of basic emergency and disaster awareness and response planning more broadly as part of health programs everywhere, including in the low-income settings where global health programs operate.56,115,114,117 Rarely are such technical strategies included in current global health programs.

4. Align Current Global Health Programs More Firmly Within a Larger Framework of Sustainable Development

The increased interest in and resources for global health over the past decade have already produced many advantages and positive impacts, including increased rates of coverage of essential services,30 declining child mortality, and increased uptake of complex interventions. However, the constantly increasing number of global health organizations raises transactions costs for poor countries and contributes to inefficiencies for all stakeholders. With the unlikely prospects for a return to a traditional institutional architecture led by one or a few major global health institutions, a different self-organizing principle for global health action has been suggested. This principle is based on an emerging normative “source code” for global health action that is jointly stewarded by involved organizations and individuals, in the same way that open source software is jointly stewarded by the community of collaborators.109 If that correctly characterizes the situation in global health, then the overarching constructs of sustainable development, the specific constructs of climate change, and long-term efforts to reduce the negative impact of climate change on global health warrant a central position in the global health source code. Of special note, family planning, a relative loser of resources in the past decade of expansion of global health efforts,108 is powerfully aligned with all thoughtful approaches to sustainable development, is a critical factor in mitigation and adaptation to climate change, and deserves the concerted support and advocacy of all elements of the global health community.94 Action to include these concerns in the source code could include explicit attention to these sustainable development considerations in funding decisions by large foundations and other funders. Other principles, such as reducing greenhouse gas emissions, promoting local development and production, using renewable energy, and promoting responsible land use, are also important and would yield other global health co-benefits.125,126

Discussion

Global warming at the rate of fractions of a degree per decade can be hard to reconcile with the immediacy of most current global health efforts, often characterized in terms of hundreds or thousands of lives lost per day. Nevertheless, for many reasons—the broad global scientific consensus that anthropogenic climate change is occurring; the virtual certainty that it will have its most severe impacts on the same poor, mostly tropical countries that are now the focus of global health efforts; and the consistent finding that actions taken now can be much more powerful to prevent and prepare for climate change—should sensitize all concerned with global health to this looming threat and galvanize awareness and action.

We have suggested four domains for global health to pursue additional dialogue and translate concern into action. The first of these—getting the full attention of the global health community and raising awareness of the importance of climate change in global health
efforts—may be the greatest challenge. Once awareness is raised, quickly integrating, operationalizing, and evaluating appropriate mitigation and adaptation activities within global health programming will be essential. For the global health community to play its natural vanguard role concerning climate change and health in low-income countries, innovative thinking about prevention and preparedness will need to be catalyzed, experiences will need to be shared, and best practices disseminated. The Sustainable Clinical Trials Group mentioned earlier is one good example of innovation and knowledge sharing in this area. Many more will be needed.

The other three domains proposed for near-term action already have benefited from the attention and activities of “early adopters,” but will see increased benefit from broader engagement of traditional global health leaders. Collaboration on strengthening the evidence base is a traditional role of global health science, and collection and assessment of climate-related data in connection with ongoing global health programs may involve only modest cost and yield new scientific findings of great interest and import. Many current interventions in global health may either be affected by climate change, or could be important in prevention and preparedness for worsening climate-sensitive health outcomes. Analyzing and documenting them as such may provide new opportunities for both science and advocacy, and potentially for attracting additional resources.

At the height of the cold war, physicians emerged as a key constituency to articulate the urgent threat to health represented by nuclear weapons of mass destruction. The IPCC’s recent Fourth Assessment, Climate Change 2007, warrants a similar call to action. Global health practitioners in particular, who have closer relationships, access to, and professional interdependence with low-income populations at the highest risk, have a complex opportunity and obligation: to anticipate the global health effects of climate change; rapidly gather data and adapt ongoing research to investigate the likely health effects of climate-sensitive diseases in the developing world; weigh these effects against the other significant burdens of disease in poor countries; and act to mainstream sustainable development principles and climate change awareness into global health programming. Through such efforts, global health can bear witness to the inequity of the health burdens created by climate change, minimize the extent of future climate change, and maximize public health preparedness in the least-served parts of the world.

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