CHAPTER 15

HEALTH HAZARDS

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1 Introduction

Humans are social creatures. Our choice to live in cooperative groups has proven to be an eminently successful survival tactic. It is also clearly a choice borne from preference, as we enjoy the enrichment provided by community living, and the interesting social complexities gained through membership of a social group. But perhaps even more fundamental than our social needs is the fact that we are also biophysical creatures. Dependence upon the healthy functioning of earth's biophysical systems is a matter of survival, not merely preference.

Our social systems and cultural practices evolved in response to our elected congregation into communities, whereas human physiology and physical needs evolved in response to the earth's environment. Accordingly, we are superbly adapted to this environment (Richardson, Steffen, et al. 2009). Our apparent preference, and indeed survival, in non-natural environments such as urban centers is a relatively recent phenomenon, made possible only by our exceptional adaptive capacity, application of technology, and social organization. However increasing evidence suggests these artificial environments carry health risks.

Widespread anthropogenic degradation of ecological systems and now interruptions to global climate are creating an environment that does not suit our physiology, and hence is challenging the survival of our species.

Projected average global warming by 4 to 6 °C by 2100 will transform the planet to a very different world to the one in which human physiology (and existing ecologies) evolved. Climate change is currently having, and perhaps more alarmingly, will increasingly have wide-ranging and mostly adverse impacts through multiple pathways. Warming poses direct health threats via exposure to extremes of heat beyond our physical tolerance. Ecological systems threatened by climate change concern food yields, infectious pathogens, and river health. These supply the food, air, and water we need to survive, so by interfering with these, we are disrupting the core building blocks for human health.

Developing countries, already experiencing initial impacts, are predicted to suffer the most dramatic impacts of continued warming. Unless we rapidly reverse the process, continued degradation and destruction of life support systems will create widespread deprivation, generate resource competition, and will ultimately disrupt the social structures

responsible for peace, security, and stability. This chapter outlines how these changes threaten population health and the ultimate survival of our species.

2 Climate Changes and Human Health

A warming climate delivers significant changes to climate systems, which in turn, have profound impacts on ecosystems. The following sections describe the links between climate change interfering with ecosystems and social infrastructures and human health and well-being.

Figure 15.1 depicts the various pathways of impact. Climate change warms the planet and creates anomalies in precipitation patterns, increases in extreme weather events, heatwaves, and rising sea levels. Direct pathways include the acute and chronic stress of heatwaves, and the immediate trauma from increased bush fires, storms, flooding, and coastal inundation. Indirect pathways occur when heatwaves or rainfall shortages reduce crop yields, or when altered distributions of vectors and pathogens produce changes in the epidemiology of infectious diseases. Butler classifies these as primary and secondary impacts (Butler and Harley 2010). Butler's tertiary effects include famine, resource competition, social disruption, conflict, war, and significant population displacement, which carry serious widespread implications for governance, health, and health inequity.

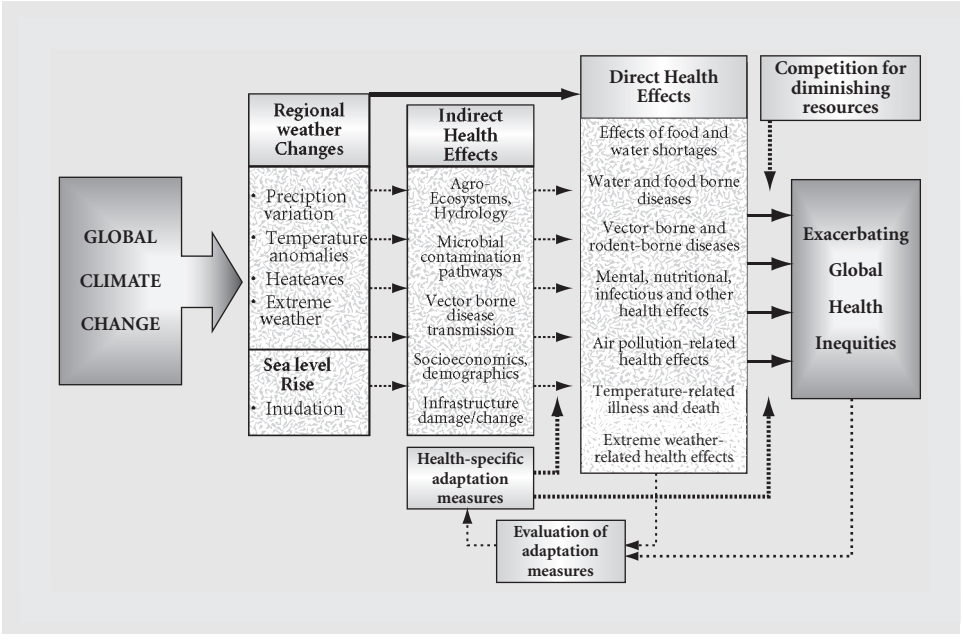

FIGURE **15.1** Pathways that climate change can affect human health and well-being. (Hanna et al. 2011; adapted from McMichael, Campbell-Lendrum, et al. 2003)

3 Heat Exposure

Temperatures are rising, and the first half of 2010 was the warmest on record, with heat extremes experienced on many continents (National Climatic Data Center 2010). There is an upper limit to human tolerance to heat exposure. Complex physiological and behavioral thermoregulatory systems maintain our core body temperature within the very narrow tolerance range of one degree around 37 °C. Eighty percent of the energy produced by exercising muscles is heat, which must be dissipated, and this heat transfer between the human body and the environment depends on climate and clothing. If air temperatures exceed 35 °C, the human body can only maintain normal core temperature by the mechanism of sweat evaporation. Sweating becomes ineffective in humid conditions and when wearing certain clothing, such as personal protective gear. The threat to human health from a warming climate is less from the rise in average global temperatures than increases in frequency and intensity of extreme heat events, beyond physiological comfort and capacity to work and function.

Under a medium-high emissions scenario, by 2020, 2050, and 2080, the number of hot days could increase by 2.1, 3.6, and 5.1 times relative to 1961–90 (Cueto, Martínez At, et al. 2010). In many urban populations, an average 2 °C rise in temperature would increase the annual death rate by an estimated doubling or more, due to hotter heatwaves. Heatwaves are already more frequent and more intense than in the past, and the health toll is apparent. The 2003 European heatwave was responsible for a total of over 60,000 premature deaths. Unprecedented heatwaves across the United States, Canada, Europe, Asia, and Russia in 2010 caused major disruptions to power, interrupting transport, air conditioning, and exacerbating heat deaths. A heatwave in India and Pakistan in June 2010 saw temperatures reaching 53.5 °C (128 °F) (Pakistan Meteorological Department 2010).

Communities unused to high temperatures are especially at risk, as they have not previously had need to develop behavioral or technical adaptive strategies via housing design and air conditioning, and they are not acclimatized. The European heatwave is a case in point. In all communities exposed to heat events, it is the elderly, the socially isolated or immobile, the very young, and people with chronic diseases, who are considered most vulnerable to extreme heat events. Cardiovascular disorders accentuate risk as extreme heat places additional load on the heart. Cognitive impairment, diabetes, cancer, and obesity also elevate susceptibility to heat stress. Prescribed medications such as anticholinergics, antiparkinsonian agents, and some antipsychotics and tranquilizers can interfere with the body's thermoregulatory system and fluid and electrolyte balance (Beggs 2000; Kwok and Chan 2005). Settings are also vitally important. For example, in urban environments, upper floor dwellings increase heat exposure risks where cooling and ventilation is limited, as they accumulate heat. High night-time minimum temperatures also exacerbate health risks, and the urban heat island effect can raise temperatures in highly urbanized areas by as much as 6 °C (Erell and Williamson 2007).

People working or needing to be outdoors, and those without access to cooling are another high risk group (Hanna, Kjellstrom, et al. 2010). Their risk is exceptional during extreme heat events, but they are also susceptible during hot days that are not extreme. Unless acclimatized and very fit, humans cannot withstand exercising in hot temperatures for any length of time, and the capacity to be productively active is halted. By the 2080s, population-based

labor work capacity is predicted to fall by 11 percent to 27 percent due to rising heat (Kjellstrom, Kovats, et al. 2009). Additional warming to areas of the world that are already warm is deeply concerning. To achieve the same productive output, workers may need to work longer hours, or more workers must be employed. Employers will need to consider economic costs of lost production and/or implementation of occupational health interventions protective against heat exposures. People remunerated by output, and those not at liberty to self-pace may be pressured to continue working beyond their thermal tolerance limit. Chronic heat exposure takes a heavy toll where workers are chronically dehydrated, and the result is diminishing health, performance, and cognitive ability, which further impoverishes. Global warming therefore presents both economic and health threats.

Heat stress injuries range from mild through to organ failure and death. Heat is dangerous because the victims of heat stroke often do not notice the symptoms, and therefore do not take steps to alleviate the risk. This means that employers, colleagues, family, neighbors, and friends are essential for early recognition of the onset of the conditions. The affected individual's survival depends on others to identify symptoms, provide assistance, and to seek medical help. Early signs can include disorientation, confusion, euphoria, or an unaccountable irritability or complaints of a general malaise. The skin is moist, the pulse rate is typically rapid and weak, and breathing is rapid and shallow.

If left untreated, heat exhaustion can progress to heatstroke, a serious, life-threatening condition characterized by a high body temperature (>39.4 °C [>103 °F]). Signs and symptoms include skin that is red, hot, and dry (sweating has ceased); rapid, strong pulse; throbbing headache; dizziness; nausea; confusion; and eventually unconsciousness (Parsons 2003). Symptoms can progress to multiple organ system dysfunction and death. Prevention is the most effective treatment, by allowing the person to rest in a cool environment, with access to food and plenty of fluids (1–2 liters/hour).

In 2009, temperatures in the outer suburbs of Melbourne (Australia) reached 48 °C. Associated with winds over 100 km/hour, eucalyptus wildfires reached an intensity never witnessed before, burning over 2,000 homes, over 60 businesses, and causing the loss of 173 lives (Department of Human Services 2009). The pattern of intense fires following heat extremes and droughts is similarly affecting many other countries, and carries long-lasting effects on infrastructure and business, including tourism.

Severe mental health effects can follow the trauma of seeing charred landscapes that were once beautiful forests. The term 'solostalgia' has been coined to describe the distress caused by environmental change (Albrecht, Sartore, et al. 2007) which can arise following storms, floods, fires, or droughts. Loss of family, friends, and livelihoods, especially when there appears to be limited opportunities to recover, are predictors of mental health issues. Children witnessing these events and the impact on their supporting adult generation will inevitably be impacted as they ponder their uncertain future (Hanna, McCubbin, et al. 2010).

4 Policy Responses to Heat

With certain notable exceptions, such as the mining industry and the military, Occupational Health and Safety legislation and guidelines have given limited attention to protecting workers against excessive heat exposure. Consideration is particularly needed to protect

the health of workers in the emergency and essential services during heatwaves (Hanna, Kjellstrom, et al. 2010). Public health responses depend on the ability of fire-fighting, police, ambulance, caring, and nursing sectors to function at maximum capacity and efficiency during the most adverse conditions for extended periods of time.

Many nations are rolling out heat warning systems (HWS) but they are not sufficient by themselves to prevent poor outcomes, especially among low-income, minority, and politically marginalized groups with fewer economic opportunities. For example, old and poor housing stock is less likely to have effective cooling. The poor do not have resources to modify their homes, nor incentives to adapt; they may also be less likely to work in cooled environments, and be less able to travel to cooled public buildings. Inability to escape the heat increases their exposure and exacerbates health inequities. HWS need to be associated with a platform of health protective actions across a range of sectors, which must be well considered, and locally feasible. Some actions involve national or state polices, such as national health promotion campaigns, and others can be enacted at the local scale, but national programs are often needed to spearhead their adoption.

Climate change will likely reinforce and amplify current as well as future socio-economic disparities leaving the disadvantaged with greater health burdens. The US CDC is focusing on increased heat events to reduce the impacts of heat events on vulnerable populations (CDC 2009). Technical responses such as evacuations to cooling centres are complex. Preconditions to development of proactive policies are, first, an acknowledgement that heat events are a current and increasingly future risk, that is, the will to act, and secondly, sufficient economic capacity to initiate strategies. Environmental justice movements can assist to motivate governments to invest in health protection, and public infrastructure and support services. Lessons can be learned from Australia when in the Victorian 2009 heatwave, train lines buckled in the heat and peak electricity demand led to power blackouts which interrupted air conditioning, caused traffic chaos with traffic lights affected, and compromised emergency services in their attempts to reach people in need. Hospitals and shopping centers were inundated (overwhelmed) by people seeking a cool environment. An outpouring of community reaction prompted government action.

5 Extreme Weather Events

Climate change is predicted to bring extreme rain events, and the trend is already obvious. Hot air absorbs more water and carries more kinetic energy, which increases the ferocity of storms. Insurance industries report that Category 5 storms are becoming more frequent globally. The greater destructive power of these stronger winds in cyclones, typhoons, and hurricanes generate significantly more injuries, widespread loss of homes, and greater damage to infrastructure and livelihoods. Economic costs of these events are high, and expenses such as repairing roads, bridges, and buildings can curtail government expenditure on proactive investments in capacity building and reducing inequities.

Heavy rainfall events create flooding and landslides. The hottest year to date, 2009–10, brought a series of catastrophes. Floods in Pakistan affected more than 21 million people, caused over 80,000 deaths, displaced 700,000 people homeless, destroyed crops, contaminated water supplies, and ruined food supplies. Russia's extreme heatwaves and peat fires

near Moscow exceeded its response capacity, and generated dangerous air pollution. The destruction of over 20 percent of Russia's crops led to an export freeze which inflated global food prices, and diminish the amount of food that aid agencies can afford and distribute. Flooding and landslides in China in July 2010 affected over 29 million people and left one million people homeless. The reinsurance company, Munich Re reports that weather-related catastrophe losses have increased by 2 percent each year since the 1970s (Munich Re 2009). Typhoon Ketsana submerged 80 percent of the Philippine capital, affecting over 4.4 million people in Manila and neighboring provinces. In Vietnam, landslides and flash floods killed 162 people. In Cambodia and Laos, hundreds of families lost household items and food stocks to rapidly rising flood waters. Floods destroy crops and infrastructure, and by interrupting food sources and contaminating water supplies, also bring diseases such as cholera. Meanwhile women have special needs because they continue to give birth, and nurture children regardless of the dangers surrounding them.

6 Food and Water Security

Increased food and water insecurity threatens millions with hunger and malnutrition. Long-term extreme drying trends are being observed in North and South America, Africa, the Middle East, China, and other parts of Asia. Sub-Saharan Africa has shown a marked decline in rainfall leading to an average decline in discharge of some watercourses in the range of 40–60 percent since the early 1970s (FAO 2010).

Water is also a health issue. Droughts diminish food yields, raise prices, and reduce water availability for drinking and sanitation. Climate change will exacerbate droughts, and yield more extreme precipitation events and more fierce storms, and will therefore interrupt food and water supplies. For millions of people these basic necessities for human life, food, water, and shelter are already being interrupted by increasing climate extremes.

Currently, almost 1 billion people live worldwide in arid lands; one-fifth of these are in Africa alone. Arid and dry semi-arid land are defined as less than 120 days length of growing period, where temperature and soil moisture conditions are favorable to crop cultivation. Arid and dry semi-arid areas in Africa are predicted to increase by about 11 percent, making it at risk of being severely constrained for crop agriculture.

More than 70 percent of current world population, 4.2 billion people live in the 80 poor food-insecure countries, and in 2010, over 1.2 billion people, more than one-sixth of the global population, are hungry and undernourished (FAO 2009, 2010). This hunger crisis is historically unprecedented, with several factors converging to make it particularly damaging to people at risk of food insecurity. These were partly climate/environment induced. Widespread droughts reduced global cereal yields and sparked the 2006–8 food crisis, which pushed the prices of basic staples beyond the reach of millions of poor people. Two years later, food commodity prices remain 17 percent higher. This protracted problem plunged an additional 172 million people into hunger, and forced many poor families to sell assets or sacrifice healthcare and education to purchase food (Myers 2010).

Among children and pregnant women, malnutrition has a multiplier effect, accounting for more than a third of the disease burden of children under age 5, and over 20 percent of maternal mortality. Diarrheal diseases arise from insufficient clean water or lack of

sanitation, and diminish the body's capacity to absorb nutrients. People with insufficient access to nutritious food are more susceptible to diseases, and being deprived of sufficient clean water therefore doubly compromises their prospects for health.

The importance of the various dimensions and the overall impact of climate change on food security will differ across regions and over time. All 'normal' climate patterns are expected to change and alter local agricultural productivity, therefore every country will be exposed to climate change, and the net impact is expected to be negative. Perhaps most importantly, sensitivity to these impacts will depend on the overall socio-economic status of the country as the effects of climate change set in.

Some areas will have longer growing seasons, less snow, and more rainfall, however as farmers transition to novel production new pests and challenges will emerge. In some developed countries, notably parts of North America, the Former Soviet Union, and northern Europe (Fischer, Shah, et al. 2005) many reports suggest that some yields might increase. The United States produces 41 percent of the world's corn and 38 percent of the world's soybeans, two of the four largest sources of caloric energy produced and are thus critical for world food supply. In the US staples such as corn and soybeans can tolerate temperatures up to 30 °C, but temperatures above these thresholds are very harmful. Without shifting the current growing regions average yields are predicted to decrease by 30–46 percent under the slowest warming scenario (B1—International cooperation towards global sustainability), and decrease by 63–82 percent under the most rapid warming scenario (A1FI World markets and technology fail to deliver sustainable solutions, rapid economic growth fossil fuel intensive) before the end of the century (Schlenker and Roberts 2009). The immediate impact this will bring for wealthy countries is unknown. Inevitably, the poor will suffer most, especially farmers unable to transition to new crop varieties, or move to new growing areas. Communities depending on unsustainable agriculture will also be at risk.

An average global 2 °C rise in temperature could reduce cereal grain yields in South Asia and Sub-Saharan Africa by 5–20 percent. Southern Africa could lose more than 30 percent of its main crop, maize, in the next two decades, with possibly devastating implications for hunger in the region. Warming of more than 3 °C is expected to have negative effects on production in all regions (IPCC 2007a).

Elsewhere, different climate change impacts are also threatening food security. Some of the most productive agricultural areas, such as the Mekong Valley are delta regions which will become inundated by rising sea levels. Such regions covering 60–90 million hectares feed millions of people. Small Island States are also at extreme risk of losing their agricultural lands and water supplies, bringing into doubt their capacity to survive on their traditional homelands. The risk for them is livelihood, health, and culture.

The world's fish stocks are threatened by climate change. Ocean uptake of anthropogenic CO_2 alters ocean chemistry, leading to ocean acidification and reduction in calcium carbonate ($CaCO_3$) used to make the shells and skeletons of the marine food web (Doney 2010). Fishing is a major industry for coastal communities, and the absence of fish as a protein source risks the nutrition of millions of people worldwide. On a more positive note, fisheries do have a potential for autonomous adaptive capacity. Climate variability has occurred throughout history. Natural systems and fisheries have developed a capacity to adapt that may help them mitigate the impact of future changes. Marine life can move locations if conditions and food sources suit. Whether migration of sufficient elements of marine food webs can occur to sustain survival is yet to be seen.

Complex systems are not insular. Fish stocks may be challenged as climate change places extra pressure on marine food systems. Population growth and food shortages may drive more people to seek nourishment from the seas. Land-based food shortages may also drive more intensive farming patterns and chemical contamination of rivers, and interfere with water runoff. Multiple stresses can cause fish stocks to collapse.

Existing projections indicate that a future population of 9 billion people coupled with economic growth will require a doubling of current food production by 2050, including an increase from 2 billion to>4 billion tons of grains annually. This becomes problematic, as economic advancement has been accompanied by a shift in food consumption patterns from crop-based to livestock-based diets which are less effective in terms of land and water use per unit energy and protein produced. Against this rising demand, urban growth extends further into agricultural lands, and crop yields diminish through the effects of increased heat, extreme weather events, and water shortages, and world phosphate supplies are depleting. Irrigation, fertilizers, and pesticides, land-clearing, and new crop varieties addressed the world's last food crisis, but these strategies are now unadvisable, for they exacerbate environmental degradation. As the world continues to warm, the problem of feeding a growing population is expected to become a major humanitarian challenge.

7 Infectious Diseases

The prospect that climate change could further escalate the global burden of disease due to infectious diseases is another source of growing concern.

Harm to health is less obvious via secondary effects from climate change, such as when diseases arise due to alterations in the ecology of vectors, parasites, and host animals (Butler and Harley 2010). Most studies show an increase in disease transmission results from alterations in environmental conditions. For example, vector biting rates are 300 times higher in deforested areas of Peruvian Amazon compared to intact forest. Building micro-dams and waterways are beneficial in securing water supplies, but also increase malaria vector habitat and infection rates by a factor of seven in nearby villages. Draining wetlands where mosquitoes breed can eliminate local sources of malaria but also reduces water quality and increases risk of diarrhea and water-borne diseases (Myers 2010). Increasing urbanization and the growth of urban slums that lack sanitation and clean water provide fertile ground for infections. Human forays into virgin areas of forests have brought us into close contact with animals and their pathogens. Pathogens can sometimes change hosts and infect humans who are not adapted to these zoonotic diseases, unlike the original animal host. Climate adaptive strategies therefore need careful planning.

Climate change is expected to impact vector-borne disease epidemiology. Temperature and rainfall patterns affect the distribution of disease vectors, and also reproductive cycles and biting frequencies. These determine vector capacity to transmit pathogens, such as those responsible for Malaria and dengue. Studies in the United States suggest that recent increasing temperatures contribute to the 35–83 percent higher incidence of reported West Nile Virus infection. With regard to future trends, the key factor for public health is the migration of vectors into areas previously free, where resident populations have yet to develop immunity, nor developed strategies to protect health and minimize harm.

However some conditions are reportedly less favorable to certain infectious disease vectors, so the area is attracting considerable debate in the literature with regard to net global impacts. For example there were concerns about a rise in malaria cases in the UK and the US, but there have been marked global declines in the disease and a substantial weakening of the global correlation between malaria endemicity and climate (Gething, Smith, et al. 2010). The Malaria Atlas Project funded by the Wellcome Trust study found preventative measures such as the widespread use of bed nets have outweighed the effects of climate warming on malaria. This example provides a positive demonstration of coordinated public health investments countering climate-induced health burdens.

In addition to affecting the health of individuals directly, infectious diseases impact whole societies, economies, and political systems. The loss of qualified personnel, most notably to human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), tuberculosis (TB), and malaria limits the capacity of crucial sectors involved in nation building and sustained development, such as health and education. These and other infectious agents not only take an enormous physical toll on humanity, but also cause significant economic losses both directly in the developing world and less directly in the developed world. AIDS, TB, and malaria are increasingly being acknowledged as important factors in the political and economic destabilization of the developing world.

8 Combined Impacts

Many of the impacts of climate change are interrelated. For example heat and droughts are often co-linked, along with fires and water shortages. Floods precipitate disease outbreaks such as cholera and other diarrheal disease, and also wreak damage to infrastructure and can disrupt food and water security. Regions will therefore be commonly exposed to multiple, consecutive, or sequential impacts. The interaction of these and associated effects may result in profound and unpredictable impacts. Reparation of buildings, bridges, agricultural lands, and breeding stock can take many years to be fully effective. In many instances, residual deficits to national infrastructure, livelihoods, social capital, and food supplies will linger. Responses to even quite gradual changes to climate may not be complete before another event unfolds. The risk, especially for communities with limited adaptive and recuperative capacity, is that climate change will exert constant downwards pressure on their ability to recover.

A consensus has emerged that developing countries are more vulnerable to climate change than developed countries, and despite their own negligible contribution to greenhouse gas emissions, their health outcomes are already decidedly worse (St Louis and Hess 2008). The most important risk factors for death and disability in poor countries differ strikingly from those in the developed world, because of the predominance of agriculture in their economies, the scarcity of capital for adaptation measures, their often warmer baseline climates, and their heightened exposure to extreme events. Poor communities have fewer resources to respond to climate change health threats such as increased natural disasters, food and water insecurity, and changing disease distribution. This existing disproportion in risk of being affected by weather-related natural disasters is almost 80 times higher in developing countries than in developed countries, and women are up to 14 times more likely than men to die from natural disasters (Neumayer and Pluemper 2007).

Developed countries cannot be complacent. They will not be spared, as indicated by extreme weather events such as the 2003 European heatwave, the drought, bushfires, and extreme heatwaves in southeast Australia, Hurricane Katrina, and many other events. Whereas it is impossible to say with certainty that any specific weather event is a result of climate change, the significant increase observed in both the frequency and intensity of extreme whether events—heatwaves, storms, and floods—is entirely consistent with climate change (IPCC 2007b).

9 Climate Change: Deepening Global Inequities

The picture painted thus far focuses principally on the most vulnerable populations; many of these are already confronting the early effects of climate change. Unabated, global warming will significantly interrupt food supplies, water quality, and disease transmission to also significantly impact developed countries

Climate change is already bringing significant perturbations to human life support systems in many regions, notably among water and food security, in some cases with disastrous results. Post-disaster health effects persist long after the global attention moves on. Physical deterioration and chronic disease can launch a downward spiralling of health status, and family economic well-being, and produce intergenerational effects from childhood stunting and learning deficits. Mental health deterioration can also follow these events (Oxfam 2009). Combined, these can damage social functioning and group or family cohesion, which can then drive further deterioration of living conditions.

A healthy population is key to high agricultural productivity and hence food security. Reductions in food production and nutrition can lead to higher rates of malnutrition and susceptibility to other diseases such as HIV/AIDS, which in turn affects agriculture through loss of labor, knowledge, and assets (World Bank 2008). Hunger and malnourishment therefore creates a vicious circle of disadvantage. Their poverty trap acts as a *positive feedback loop*. This occurs when a system responds to a perturbation *in the same direction* as the perturbation, thereby exacerbating the original impact. A positive feedback loop can run out of control, and result in the collapse of the system (Hunter 2007). Climate change exacerbated hunger can tip populations into a state where they have not the human resources to grow the food they need to survive. As the majority of people in developing countries employ labor-intensive methods of food production, any changes in the health status of the community as a result of climate change is most likely to also affect future food security.

Climate change has therefore major repercussions for the social determinants of health. Inequalities in these determinants are the major cause of health inequities within countries and between countries. Socio-economic status determines where one lives, and therefore can influence the environmental determinants (Lin 2008). By acting on these social causes, climate change could further entrench a vicious circle of disadvantage by greatly exacerbating global health inequities among current generations and establishing a profound intergenerational inequity (Walpole, Rasanathan, et al. 2009).

Although vital for global health, strategies to reduce carbon emissions will not necessarily improve health equity. Ill-considered policies such as flat pricing mechanisms could easily be regressive in terms of income inequality by increasing the price of essential items. Low-income households, even those in developed countries, are struggling to afford basics. Policies that exclude consideration of impacts on the poor, by means such as subsidies, will result in them paying a proportionally greater financial burden, thereby increasing income inequality and worsening health inequities.

Climate change therefore has the potential to further widen the gap between rich and poor. Countries that are existing at the edge of survival have minimal resilience to withstand additional shocks. By the 2080s, the total population of *food-insecure* countries is projected to increase to 6.8 billion, or about 80 percent of the world population at that time (Fischer, Shah, et al. 2005). Such disparities have the capacity to destabilize social structures in rich and poor countries. Environmental stresses caused by climate change exacerbate competition for soil and water resources; they place high demands on disaster risk management and on planning and systematically prioritizing the allocation of limited public funds. Disrupted markets, shortages of goods, and strained social structures can exceed the capacities of struggling governments to maintain services and order within and beyond their localities. When a disaster occurs, there is the risk of collapse of public order, especially in megacities.

Underlying determinants of health inequity and environmental change are signs of an economic system predicated on asymmetric growth and competition, shaped by market forces that disregard health and environmental consequences or values of fairness and support (Friel, Marmot, et al. 2008). Climate-induced insecurity poses a population health threat. Adaptive health-maximizing strategies are needed that narrow the gap, and lessen the within country and between country disparities in access to resources, opportunities, and health.

10 Adaptation

Adaptation landscapes are fundamentally different in rich and poor countries, and this difference also has implications for equity and for global health policy (St Louis and Hess 2008).

The Least Developed Countries Fund (LDCF) was established under the United Nations Framework Convention on Climate Change to address the special needs of the 48 Least Developed Countries (LDCs), regarded as especially vulnerable to the adverse impacts of climate change. Support included preparing and implementing National Adaptation Programs of Action (NAPAs) to identify urgent and immediate needs of LDCs to adapt to climate change. While the NAPA process is aimed at achieving procedural justice, in practice often both procedural and distributive justice concerns are unresolved because of lack of trust, local or national political tensions, lack of capacity of locals, and corruption. The refusal of the US to contribute to the LDC Fund served to slow down the process of assisting vulnerable nations (Global Environment Facility 2008).

As many health determinants are social and environmental in origin, many health maintenance strategies lie outside the formal heath sector. For example the provision of

safe food and safe water is a health necessity, and is therefore a key health issue, although not regarded as health sector activity. Climate change threatens human survival, initially primarily in the developing countries, and ultimately globally (Schneider 2009). The vulnerability of those suffering current or potential food, water, and shelter insecurity should therefore be encapsulated into all policies across government. For example, agricultural policies should be designed to develop capacity to ensure continuous affordable food supplies can be maintained during the immediate period post disaster events, as well as for the longer term. Strategies can include education and practical assistance, such as seeds, to produce food that can flourish in the 'new' local climate. This includes ensuring women have rights to land tenure, and to form cooperatives. In urban areas, establishment of community gardens can also assist food security, this also applies in developed countries (Dixon, Donati, et al. 2009).

Adaptation strategies within the health sector include augmenting public health infrastructure. The key elements of population health are promoting health and well-being; by providing the supports for people to self-manage their own health, and the health needs of their families. Water security must therefore take high priority in water scarce lands. Options to boost self-sufficiency and resilience therefore include installation of community water catchments, reuse and recycle infrastructure, community water storage capacity, and providing education on requirements to manage and maintain clean water systems. Renewable energy sources are necessary to support pro-health activities. Health services include bolstering disease surveillance and prevention and treatment of infectious diseases. Disease prevention includes strategies for families to avoid contact with contagion, building of sewerage systems, education to boil water during disease outbreaks, and provision of facilities to heat water.

Preparedness also includes capacity building to cater for surge in health care demands from heatwaves, fires, floods, and storms, and catering to the recovery phase, sheltering the homeless, and providing food, water, protection, and counselling services. The health sector was slow to embrace climate change, and recognize the health threats, so there is much yet to be done in terms of preparation, skills building, training the health professions, and educating the public. Vulnerability assessments and monitoring and surveillance systems will need to be modified to ensure programs remain effective under a changing climate (Ebi 2009).

Another category of positive adaptation is promoting strategies that bring *co-benefits*. Co-benefits occur when one action carries an additional secondary positive result. Shifting to bicycles as a primary urban transport mode reduces car mileage and reduces carbon footprint. Side benefits are numerous: a more amenable environment, cleaner air, and health benefits are gained from physical exercise, such as a reduction of cardiovascular disease, diabetes, and obesity.

The condom should be classified as a powerful climate change adaptive strategy, promoted as reproductive rights rather than as a form of population control. Family planning can be made available as a method of empowering families to control the number and timing of children and help reduce unwanted pregnancies. The health advances in childhood survival rates and maternal health gained from access to effective family planning are well established. Global availability of the condom could reduce population by 1–2 billion by 2100, thereby reducing demand for limited resources, and ultimately, greenhouse gases (AAAS 2009).

Failure to mitigate against and to adapt to climate change is certain to bring human misery on a grand scale. Oxfam and Global Humanitarian Fund reports testify to the

millions of people alive today who are suffering through extreme shortage of the basic necessities for life (Global Humanitarian Forum (GHF) 2009; Oxfam 2009). This will generate millions of refugees as people move in search of opportunities to feed their families. The conflict in Darfur has been attributed in part to climate change and environmental degradation (see Gilman et al., this volume). Climate change could be the catalyst for widespread social unrest that ultimately brings this species to its knees. In conflict-prone areas, the most vulnerable group is the refugee community, the bulk of whom are women and children (FAO 2010).

11 Conclusion

The burden of ill-health attributable to climate change is likely to aggravate, and in some cases even provoke, further economic decay, social fragmentation, and political destabilization, especially in (but by no means restricted to) the developing world and countries with unstable governments.

In the face of little progress on mitigation strategies, it becomes increasingly imperative that focus is given to adaptation strategies on preparing for the health issues to come, and growing capacity to protect health, and provide safe environments, food, water, and shelter. Population health services focus on reducing inequities, and promoting and maintaining health. In essence, boosting climate change adaptive capacity therefore entails augmenting population health capacity; as these strategies build preparedness of communities to withstand health challenges such as climate stress. Such approaches also constitute 'no-regrets' polices, as they provide and promote basic human rights, and if strengthened, could deliver immediate benefits by minimizing today's health burden. Without such adaptation, community resilience will remain low, and human misery on a scale not yet seen will unfold.

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