CHATHAM HOUSE briefing paper

Climate Change and Health: Policy Priorities and Perspectives

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Centre on Global Health Security | December 2011 | GH BP 2011/04

Summary points

- The risks to population health and survival, and to social stability, from climate change are greater than have been generally appreciated.
- Further climatic influences are likely to cause direct and indirect adverse effects, including on mental health. These impacts will threaten the pursuit of health gains in lower-income regions. Population health may be further threatened by tensions, displacement and conflict.
- Global health and development strategies must address the health risks of human-induced climate change as well as promote low-carbon strategies that improve health.
- Current economic estimates heavily underestimate the risks that poor health poses to labour and capital.
- The cost of expanded emergency services, healthcare facilities, extended surveillance and prevention programmes, resettling displaced groups and falls in workforce productivity will grow, impeding other social and economic goals.
- Mitigation offers 'win-win' opportunities for enhancing population health. Meanwhile, near-term and longer-term adaptation strategies are needed to lessen the adverse health impacts of climate change.

Introduction

Human-induced climate change poses great and growing risks to human social and biological wellbeing. The impacts will affect future levels of population health, patterns of disease and death, attempts to reduce the rich-poor health gap, social stability and geopolitical security. In many respects, the 'human dimension' of climate change is broader and more far-reaching than has been generally recognized in public and policy discourse. This failure to properly consider, recognize or acknowledge the medium- to long-term threat to human societies limits both our vision of the future and our motivation to take immediate action to curb this global environmental challenge.

> 'There is increasing anticipation that, without rapid and substantial international abatement action, average surface temperatures could rise by 3–5°C by 2100'

The global climate is changing unusually rapidly. Average surface temperature has increased by almost 1°C since early in the twentieth century, including around 0.6°C since 1975.[1] This is influencing migratory patterns of birds and insects, the poleward movement of many plant and pest species, and the acceleration in the rate of sea-level rise. There is also evidence that climatic variability and extreme weather events around the world are increasing.[2]

It is not possible to predict exactly the extent and timing of future warming – and, further, the modelled projections can be under- or over-estimates. Meanwhile, there is increasing anticipation that, without rapid and substantial international abatement action, average surface temperatures could rise by 3–5°C by 2100.[3] Warming will differ greatly by latitude, especially in the northern hemisphere, where temperatures at high latitude could increase by around 7°C by 2100.[4] Rainfall patterns will also change, increasing in some regions and seasons, decreasing in others. Models consistently forecast an increase in the spread and severity of droughts during this century, often against a background of increased aridity.[5]

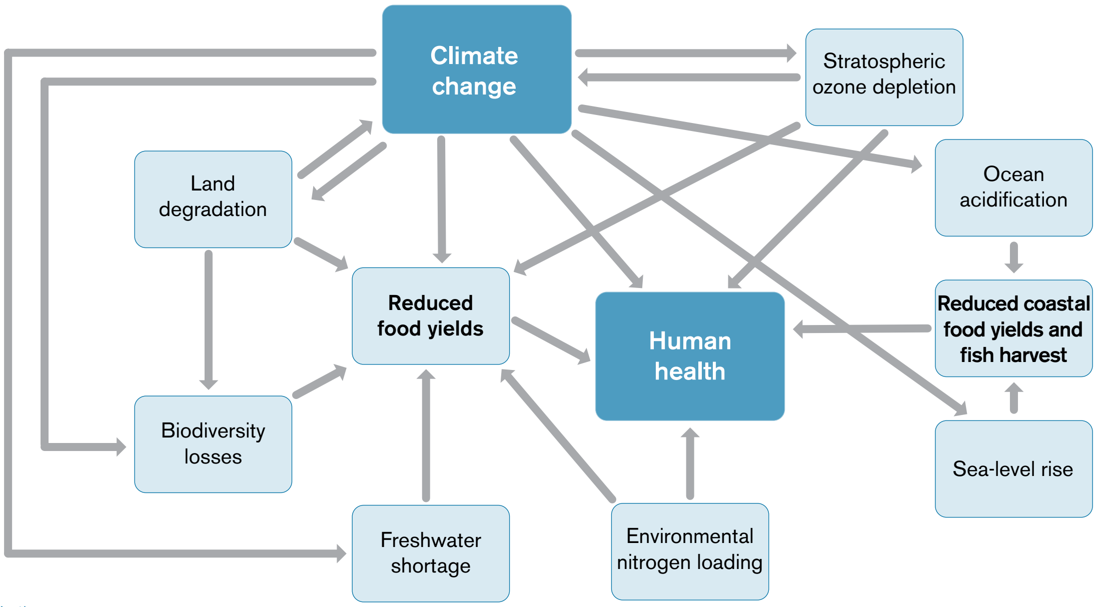
It is unlikely that climate change will cause novel health disorders. Rather, it acts mostly by amplifying existing risks to health. For example, the ongoing rapid urbanization in most low- and middle-income countries is expanding the numbers exposed to the extra local heat caused by the 'urban heat island' effect[6] – and global warming will amplify that heat exposure.

Climate change is part of a larger syndrome of human-induced changes to major systems and components of the biosphere (and its encompassing 'Earth System'). These changes are historically unprecedented in scale. They will have increasing, and mostly adverse, impacts on societies around the world and on human wellbeing, health and survival. Climate change represents one of the most serious of these threats.[7] Others include stratospheric ozone depletion, biodiversity losses, disruptions to the biosphere's nitrogen and phosphorus cycles, ocean acidification, and depletion of fertile soil and freshwater stocks.

Within this environmental 'company', climate change often acts in concert with other systemic environmental changes (see Figure 1). For example, several of these

1 Hansen, J., Ruedy, R., Sato, M. and Lo, K. (2010), 'Global surface temperature change', *Reviews of Geophysics* 48, RG4004, DOI: 10.1029/2010RG000345.
2 Schiermeier, Q. (2011), 'Climate and weather: extreme measures: Can violent hurricanes, floods and droughts be pinned on climate change? Scientists are beginning to say yes', *Nature* 477: 148–49; Rahmstorf, S. and Coumou, D. (2011), 'Increase of extreme events in a warming world', *PNAS* 108 (44): 17905-09; IPCC (2011), 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)', Special Report on Risks of Extreme Events', http://www.guardian.co.uk/environment/2011/nov/01/climate-change-weather-ipcc.
3 Meinshausen, M. et al. (2009), 'Greenhouse-gas emission targets for limiting global warming to 2 C', *Nature* 458: 1158–63.
4 IPCC (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge and New York: Cambridge University Press).
5 Dai, A. (2011), 'Drought under global warming: a review', *WIREs Climate Change,* DOI: 10.1002/wcc.81.
6 Oke, T.R. (1973), 'City size and the urban heat island', *Atmospheric Environment* 7: 769–79.
7 Rockström, J. et al. (2009), 'A safe operating space for humanity', *Nature* 461: 472–75.

Figure 1: Examples of direct and indirect influences of climate change on human health, including interactions with other major environmental stressors



Source: Author

Note: See accompanying text for explanation

environmental changes, including climate change, affect food yields. This can cause food shortages, hunger, undernutrition, susceptibility to disease, social unrest, and (as discussed below) conflict.

Figure 1 is a schematic representation of direct and indirect influences of climate change on human health (with particular focus, here, on food yields). The diagram shows that: (i) climate change is part of a wider 'syndrome' of large-scale human-induced environmental changes; (ii) many of these changes influence one another; and (iii) many of the major determinants of human health, wellbeing and social stability (e.g. food supplies, water availability) are influenced jointly by climate change and other environmental stressors.

Climate change can affect human health directly and indirectly, immediately and via more protracted processes.[8] Direct impacts can result from heatwaves and extreme weather events. Less direct effects can arise from climatic influences on mosquito populations, bacterial proliferation, food yields, freshwater flows, and, less obviously, from the adverse influences on mental health of declining farm incomes, the displacement of people and post-trauma circumstances.

Impacts on health are becoming apparent in many regions of the world. For example, recent changes in the geographic range and rate of various infectious diseases in association with local climatic changes, when viewed together, point strongly to a likely influence of climate change. Many of these impacts are widening the health gap between rich and poor, and will do so increasingly in future. This will impede the progress towards meeting the UN's Millennium Development Goals, among other things.

Healthcare systems and public health programmes will come under increasing, and often unfamiliar, demand-stress. The economic burden of providing expanded emergency services, healthcare facilities, expanded surveillance programmes, and intensified preventive programmes (e.g. mosquito control and bednet provision), and of housing and resettling displaced groups, will grow – potentially to the detriment of other social and economic development goals.

The two main tasks facing the international community are, first, to slow and then arrest the process of human-induced climate change – i.e. mitigation; and, second, to take actions to reduce the risks from climate change –

8 McMichael, A.J. and Lindgren, E. (2011), 'Climate change: present and future risks to health – and necessary response', *Journal of Internal Medicine* 270: 401–13.

i.e. adaptation. Mitigation (avoiding unmanageable risks) depends on reducing greenhouse gas emissions globally and enhancing the capacity of the planet's 'sinks', especially via re-vegetation, to absorb atmospheric carbon dioxide. Adaptation (managing unavoidable risks) primarily comprises deliberate strategies to reduce levels of exposure to climatic stresses and their environmental consequences, such as reduced food yields, along with naturally occurring spontaneous adaptations, such as physiological acclimatization to living at warmer temperatures.

Clearer understanding of the risks to population health greatly strengthens the case for urgent and effective international 'mitigation' action to abate or stop human-induced climate change. Meanwhile, ongoing climate change means that 'adaptive' strategies are needed too. This will require a heightened level of international economic aid, modified global economic processes and knowledge-sharing.

A new collaborative approach is required in how governments and communities think about, plan for and act to protect the health of populations. If we fail to mitigate, or even if we mitigate according to current projections, societies will need to adapt. Indeed, interim adaptations are already required to help protect humanity against 'natural' climate variability such as El Niño events. The Rio+20 'Earth Summit' United Nations Conference on Sustainable Development in Brazil in June 2012 provides an opportunity to place health as a sentinel measure of environmental sustainability.

Risk multiplier for health

The fact that climate change most often amplifies existing health risks and deficits has the important implication that those populations with pre-existing high rates of climate-sensitive health problems (such as the incidence of child diarrhoea, malaria, under-nutrition, or death rates from cardiorespiratory disease, or high workplace heat exposures) are liable to suffer large *absolute* increments in adverse health impact. For example, if climate change were to double the rate of diarrhoeal disease in children, then doubling the rate in a community with an already high rate would clearly mean many more actual cases than if the rate were doubled in a low-rate community.

In this early phase of human-induced climate change, it is difficult to attribute observed changes in population health confidently to recent climate change. However, prior knowledge of climate–health relationships (i.e. knowing how sensitive a given health outcome is to a unit change in, say, temperature) has enabled estimation that climate change is already causing around several hundred thousand premature deaths each year from malnutrition, diarrhoeal disease, malaria, extreme heat exposure and flooding.[9] More than 90% of these deaths are occurring in low-income countries (especially sub-Saharan Africa and South Asia), and most are in children under the age of five. The number of deaths due to climate change is almost certainly much higher, as this particular formula excludes many other climate-sensitive health outcomes (for which the basic knowledge of climate–health relations is incomplete or missing).

Recent shifts in health risks and outcomes reasonably attributable to climate change

Scientists have been able to attribute with confidence various non-human phenomena, such as sea-ice melting, earlier bird-nesting and latitudinal shifts in insect populations, in diverse settings, to climate change.[10] However, the human species presents a greater challenge. The study of health patterns in human groups and populations must deal with much 'background noise' arising from the diversity of cultural practices and individual behaviours. Many of those background factors also influence

9 McMichael, A.J., Campbell-Lendrum, D., Kovats, S. et al. (2004), *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors* (Geneva: World Health Organization), pp. 1543–650.

10 Parmesan, C. and Yohe, G. (2003), 'A globally coherent fingerprint of climate change impacts across natural systems', *Nature* 421: 37–42; Root, T.L. et al. (2003), 'Fingerprints of global warming on wild animals and plants', *Nature* 421: 57–60; Chen, I.-C., Hill, J.K., Ohlemüller, R., Roy, D.B. and Thomas, C.D. (2011), 'Rapid range shifts of species associated with high levels of climate warming', *Science* 333: 1024–25.

health outcomes, so it is less easy to differentiate the causal influence or contribution of climate change from that of other factors.

There is, however, some consistency of observations from human populations, in several continents, that allows moderate, if not yet great, confidence that certain types of health outcomes are affected by climate change. In broad terms, suggestive evidence of actual climate change impacts on health, to date, includes the following:[11]

- Recent uptrends in cyclones, storms, wildfires and flooding, and in their immediate and subsequent adverse health impacts;
- Increasing annual numbers of deaths and hospitalizations due to heatwaves in several countries;
- Shifts in the range and seasonality of some climate-sensitive infectious diseases (and their transmission 'vector' species – especially mosquitoes, ticks and fleas), including some veterinary epidemiological observations;
- Adverse mental health consequences in various rural communities affected by ongoing drying and declining agricultural productivity;
- It is also very likely that climate change, and some of its extreme-event manifestations (such as cyclones/storms in the Philippines/Vietnam region, wildfires in Russia and floods in Thailand) have contributed to recent volatility in world food prices (especially for cereal grains).

Assessing risks to health

Climate change affects many environmental and social conditions that influence the rates, ranges, seasonality and patterns of injury, disease and death. Most of the health impacts of climate change are likely to be adverse (since human biology and culture have evolved over time in relation to the prevailing climatic conditions).[12]

Even so, some health benefits are likely to result in certain regions – at least in the earlier stages of climate change. For example, if winters in some temperate countries become milder the usual seasonal excess of wintertime deaths from heart attack and stroke should lessen. Elsewhere, hotter and drier conditions in some regions would reduce the numbers and survival rates of mosquitoes, and hence the risks of malaria and other mosquito-borne infectious diseases.

'Climate change affects many environmental and social conditions that influence the rates, ranges, seasonality and patterns of injury, disease and death'

The direct health impacts of climate change are, to date, the best understood and recognized. However, the greatest adverse health consequences are most likely to result from environmental, ecological and social changes and disruptions caused by climate change. These include, in particular, regional food yields, freshwater availability and stability of the natural constraints on infectious disease transmission.

The health risks from climate change can be divided into three categories:

1. Immediate/direct risks (heatwaves, extreme weather events, air quality, etc.);
2. Indirect risks through ecological and biophysical changes and disruptions (food yields, mosquito abundance, water flows/quality, etc.);
3. Regional health risks from tensions, conflicts and refugee flows (e.g. resulting from dwindling natural resources such as food, water or coastal space).

11 McMichael, A.J. and Bertollini, R. (2011), 'Risks to human health, present and future,' in Richardson K., Steffen, W., Liverman, D. et al., *Climate Change: Global Risks, Challenges and Decisions* (Cambridge: Cambridge University Press), pp. 114–16.

12 IPCC (2007), *Climate Change 2007*.

Direct risks to health

Climatic conditions (temperature, rainfall, humidity, wind, etc.) can impinge directly on the human body. Ready examples are the health impacts of heatwaves, extreme weather events and temperature-affected air quality (especially increased concentrations of ozone). The most direct effects include deaths and severe health events (often with hospitalization) due to such exposure extremes. The severe heatwave in Europe in August 2003, lasting for 8–9 days, caused an estimated 60–70,000 extra deaths within the immediately ensuing period.[13] The severe heatwave and related regional wildfires in western Russia in July–August 2010 caused an estimated 56,000 additional deaths in Moscow.[14]

‘Once the human body’s physiological capacity to cope with increased heat stress is exceeded, the risks of functional failure, disease exacerbation and death rise rapidly’

Once the human body’s physiological capacity to cope with increased heat stress is exceeded, the risks of functional failure, disease exacerbation and death rise rapidly. This applies particularly in older persons and those with underlying cardiovascular or chronic respiratory disease.[15] These effects are associated with the fact that resting core body temperature in all people around the world is 37°C, and if the air temperature surrounding a working person is higher only evaporation of sweat protects the person from a health-damaging increase in body temperature.[16]

While the general community will experience the greater absolute burden of adverse health impacts from heatwaves, workers in various heat-exposed workplaces, both outdoors and indoors (without a cooling system), are especially vulnerable.[17] Indeed, in addition to the physiological stress and discomfort and the heightened risk of serious organ damage, workplace heat exposure can also greatly reduce productivity and economic returns to employers and workers alike.

As average temperatures rise, there will be a greater frequency of extremes of heat (and other extreme weather events) as a simple result of an ongoing increase in the annual distribution of daily temperatures. If the climate also becomes more variable, then there could be a ‘splaying out’ of the distribution at both the hot and cold ends, and a greater frequency of both extremes of heat and extremes of cold. Extreme events will also tend to increase in frequency and (more probably) severity as climate variability increases with warming.[18]

Over the past several years, scientific confidence that climate change has begun to influence and amplify such events has strengthened.[19] In related assessments, it has been estimated that the probability of occurrence of a heatwave as severe as the one that afflicted Europe in August 2003 had approximately doubled because of the underlying climate change.[20] Even so, it remains an oversimplification to ascribe any one extreme weather event solely to climate change. Rather, it is likely that most such events will in future include a contributory influence from underlying climate change.

13 Stott, P.A. et al. (2004), ‘Human contribution to the European heatwave of 2003’, *Nature* 432(7017): 610–14.
14 US National Oceanic and Atmospheric Administration (2011), ‘Natural Variability Main Culprit of Deadly Russian Heat Wave That Killed Thousands’, http://www.noaanews.noaa.gov/stories2011/20110309_russianheatwave.html.
15 Costello, A. et al. (2009), ‘Managing the health effects of climate change’, *The Lancet* 373: 1693–733.
16 Parsons, K. (2003), *Human Thermal Environments: The Effects of Hot, Moderate and Cold Temperatures on Human Health, Comfort and Performance* (London: Taylor & Francis, 2nd edn).
17 Kjellstrom, T. et al. (2009), ‘Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change’, *Global Health Action 2: Special Volume*, pp. 46–51.
18 IPCC (2011), ‘Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)’, Special Report on Risks of Extreme Events’, see http://www.guardian.co.uk/environment/2011/nov/01/climate-change-weather-ipcc.
19 Schiermeier (2011), ‘Climate and weather’.
20 Stott et al. (2004), ‘Human contribution to the European heatwave of 2003’.

Most societies will be hard-pressed to prepare for and cope with a significant upturn in extreme weather events, especially large-scale events. The flooding in Pakistan in July 2010 left one-fifth of the country's land mass under water, displacing 18 million people from their homes. At that same time, Russia was experiencing its hottest summer for 130 years, leading to serious forest and grass-land fires that contributed to many deaths and to severe damage to wheat crops.[21] In 2011, Thailand experienced its most severe floods in modern times, displacing many thousands of people from homes, causing more than 500 deaths,[22] destroying at least one-seventh of the national rice crop,[23] and leading to outbreaks of water-borne infections.[24]

Indirect risks to health

A change in climate will influence and disrupt many ecological and biophysical systems. This category of climatic influence will affect in particular food yields, water flow and quality, the production of aeroallergens (spores and pollens), bacterial growth rates, and the spatial range and activity of infectious disease vectors (such as mosquitoes and ticks). The resultant relationship between changes in climatic conditions and subsequent 'flow-on' consequences for human health will be mostly neither immediate nor obvious. Further, these influence pathways will often be modulated by other factors and conditions. For example, the spread of mosquito populations is also affected by land-use changes and mosquito control programmes, and the impact of climatic conditions on food yields will be modulated by ongoing changes in soil fertility, freshwater stocks, biodiversity and soil nitrification (see also Figure 1).

Food yields, nutrition and health

Crop and livestock yields are generally sensitive to climatic conditions. Indeed, there is recent evidence that yields can be impaired by quite small changes in growing-season temperatures.[25] Rising temperatures affect rice production, and experimental studies indicate that a 1°C rise in average night-time temperature during the later stages of rice-plant growth reduces yields by around one-tenth.[26]

Between 1980 and 2008, gains in crop yields related to factors such as technological advances seem to have been substantially offset by the impacts of rising temperatures in many of the world's cropping regions. Rice yields in India, for example, peaked a decade ago, and South Asia's 'green revolution' is now over.[27] Such negative impacts may spread beyond South Asia to include parts of sub-Saharan Africa (some regions of which are particularly vulnerable), southern Europe, the US Midwest and southern Australia.[28]

While much public and policy attention has been paid to how climate change might affect food export earnings and rural livelihoods, the ultimate manifestation of reduced food yields is impaired health – hunger, under-nutrition, stunted growth in children, susceptibility to infection, impaired adult health and premature death. Further, in a world of great disparities in wealth, climate-related falls in crop yields can have potentially disastrous effects for the poor via surging food prices. In 2011 the UN Food and Agriculture Organization food price index matched its earlier peak in 2008. This price spike is likely to have been partly caused by the disastrous impact of the mid-2010 heat and fires on the Russian wheat crop, and that price spike, in turn, is thought to have contributed to the social unrest that erupted in 2010 and 2011 in the Middle East and elsewhere.[29]

21 Gilbert, N. (2010), 'Russia counts environmental cost of wildfires', *Nature News*, 12 August.

22 Herald Sun (2011), 'Death toll from floods nears 1000', http://www.heraldsun.com.au/news/world/death-toll-from-floods-nears-1000/story-e6frf7lf-1226190452391, 9 November.

23 Agro News (2011), 'Thailand floods may cut global rice export glut', http://news.agropages.com/News/NewsDetail---5826.htm.

24 Reuters (2011), www.reuters.com/video/2011/11/07/thai-floods-spread-disease?videoId=224334638.

25 Lobell, D.B. and Field, C.B. (2007), 'Global scale climate-crop yield relationships and the impacts of recent warming', *Environmental Research Letters 2007*, DOI: 2 014002.

26 Peng, S. et al. (2004), 'Rice yields decline with higher night temperature from global warming', *PNAS* 101(27): 9971–5.

27 Lobell, D.B. et al. (2011), 'Climate trends and global crop production since 1980', *Science Express*: 332.

28 Lloyd, S.J. et al. (2011), 'Climate change, crop yields, and undernutrition: development of a model to quantify the impact of climate scenarios on child undernutrition', *Environmental Health Perspectives*, DOI: 10.1289/ehp: 1003311.

29 Lagi, M. et al. (2011), 'The Food Crises and Political Instability in North Africa and the Middle East', New England Complex Systems Institute, http://necsi.edu/research/social/food_crises.pdf.

Climate change is also likely to contribute to the increase in 'dead zones' in the world's oceans – warming reduces the solubility of gases (including oxygen) in water, which may then reduce the density and viability of fish stocks. Meanwhile, ocean fishery harvests are at risk from warming and from the threat to the base of the marine food web from the ongoing increase in ocean acidity (owing to the increased uptake of atmospheric carbon dioxide by warmer water).

Infectious diseases

Many infectious diseases, especially food-, water- or vector-borne infections, are sensitive to climatic conditions. These conditions influence pathogen maturation and multiplication, vector density and behaviour, the ecology and density of intermediate host species, and human behaviours that affect the probability of infection (e.g. crowding and displacement). There are also heightened risks in climate-related malnourished individuals (especially children) with weakened immune systems.

The incidence of food- and water-borne gastrointestinal infections such as campylobacteriosis and salmonellosis tends to rise with temperature.[30] While such risks may be largely averted in countries with sufficient public health and surveillance resources, rates of these diarrhoeal diseases rise readily in poorer and more disadvantaged population settings in response to combinations of warmer conditions, local flooding, crowding and the overloading or disruption of sanitation.

Changes in climate will affect the distribution and lifecycle of disease-transmitting insect and other vector organisms, and temperature may influence the rate of maturation and replication of the transmitted pathogens. Studies in diverse populations have demonstrated the responsiveness of Lyme disease, malaria, dengue, schistosomiasis, trypanosomiasis and leishmaniasis to climatic variation.[31] Nevertheless, the spatial and temporal patterns of such changes are difficult to predict, especially for infectious diseases with a complex ecology and non-human 'reservoir' hosts.

Malaria provides an important, somewhat tantalizing, example. In tropical and sub-tropical regions, malaria remains a major disease and cause of death, especially in young children in sub-Saharan Africa. As with many infectious diseases, the occurrence of malaria is affected by a diversity of environmental, social, demographic and climatic factors, and public health interventions. The partial success of recent public health interventions (insecticide-impregnated bednets, indoor residual spraying, intermittent administration of anti-malarials in pregnancy and effective treatment of symptomatic cases etc.) over the past decade has resulted in a decline in annual numbers of reported cases and deaths, especially in sub-Saharan Africa. It is also clear that gains in a society's wealth and literacy are associated with reductions in this disease.[32] Meanwhile, warmer conditions, perhaps with increased rainfall and greater humidity, will enhance the transmission of malaria in some locations, via aspects of mosquito and malaria parasite biology that are now well understood.

Possible changes in malaria occurrence in sub-Saharan Africa, especially in highland regions where previous transmission has been sporadic or absent, have been of particular research interest. Many studies have been carried out, for example, on malaria incidence in relation to climate trends in Kenya's western highlands. Uncertainties persist as to whether and to what extent the malaria transmission zone has reached higher altitudes in that location in association with observed regional warming over recent decades.[33]

Various other vector-borne infections have undergone changes in one or more parameters known to be sensitive to climate. For example, the ixodic ticks that transmit encephalitis in Sweden and Lyme disease in southeastern Canada have spread northwards in association with recent

30 Kovats, S. et al. (2008), 'Heat stress and public health: a critical review', *Annual Review of Public Health*.

31 Gage, K.L. et al. (2008), 'Climate and vector-borne diseases', *Am J Prev Med* 35: 436–50.

32 Beguin et al. (2011), 'The opposing effects of climate change and socio-economic development on the global distribution of malaria', *Global Environmental Change* 21: 1209–14.

33 Omumbo, J.A. et al. (2011), 'Raised temperatures over the Kericho tea estates: revisiting the climate in the East African highlands malaria debate', *Malaria Journal* 10: 12.

warming.[34] In Scotland, tick-borne Lyme borreliosis appears to be increasing in association with warming.[35] The incidence of mosquito-borne dengue has increased in Greater Manila, Philippines, over the past decade, the largest increment coinciding with the greatest year-to-year increment in warming (2005–06).[36] In Japan, the dengue vector mosquito *Aedes albopictus* has extended its zone northwards by 500 km over the past half-century in association with warming.[37] In southeastern China, as temperatures have risen over four decades, the survival zone of the water-snail that is the intermediate host for schistosomiasis (a continuing serious public health scourge in rural areas) has extended north.[38] Meanwhile, in Europe, on the veterinary front, the brown dog-tick and both the midge that spreads the much-feared blue tongue virus (killer of cattle and sheep) and the virus itself have extended northwards over past decades.[39]

Mental health

This includes the mental health consequences of droughts and other natural disasters in failing rural communities. Experience in Australia suggests that following a severe weather event (flood, fire or cyclone), up to one-fifth of people suffer the debilitating effects of extreme stress, emotional injury and despair.[40] The emotional and psychological toll can linger indefinitely, affecting the capacity to work and eroding community morale and wellbeing. Children are vulnerable to pre-disaster anxiety and post-traumatic stress disorders, and to prolonged insecurity and anxiety about climate change,[41] including chronic neuro-hormonal changes that affect long-term disease processes. There are also direct effects on mental health from conflict.

Health risks associated with environmentally induced conflicts and refugee flows

Tensions and conflicts

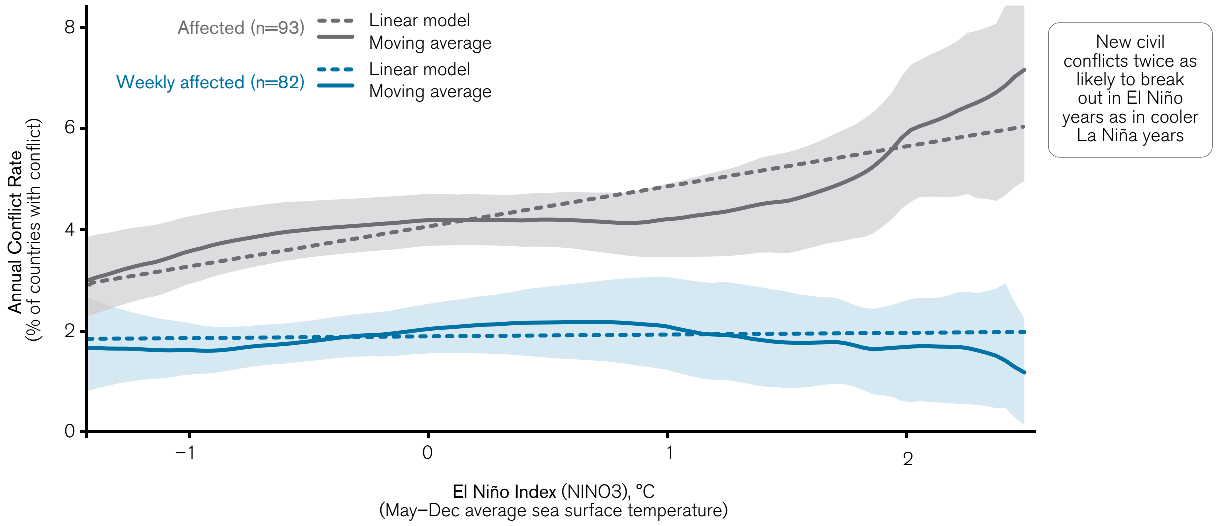
The impact of weather and climate on the risk of conflict is evident from history: climate-related starvation, outbreaks of infectious disease, loss of habitat, loss of natural resources and economic impacts are powerful sources of tension and conflict. Local wars in Africa in recent decades have peaked during hot and dry years, associated with reduced food yields.[42]

> ‘Experience in Australia suggests that following a severe weather event, up to one-fifth of people suffer the debilitating effects of extreme stress, emotional injury and despair’

Another analogue opportunity for studying the climate/health/conflict relationship comes from the consequences of the El Niño phase of the El Niño Southern Oscillation (ENSO). That great quasi-periodic cycle influences climatic conditions around much of the low- and middle-latitude world, including much of Africa, South Asia, Southeast Asia and Central and (northern) South America.[43] In the warmer (El Niño) phase, land temperatures may rise and rainfall decline – and this can result

34 Ogden, N.H. et al. (2006), ‘Climate change and the potential for range expansion of the Lyme disease vector Ixodes scapularis in Canada’, *International Journal of Parasitology* 36: 63–70.
35 Slack, G. et al. (2011), ‘Is Tayside becoming a Scottish hotspot for Lyme borreliosis?’, *J R Coll Physicians Edin* 41: 5–8.
36 Panogadia-Reyes, C.M. (2010), ‘Rainfall, temperature, relative humidity and dengue cases in Metro Manila, Philippines’, *Dengue Bulletin*: 24–35.
37 Kobayashi, M., Nihei, N. and Kurihara, T. (2002), ‘Analysis of northern distribution of Aedes albopictus (Diptera: Culicidae) in Japan by Geographical Information System’, *Journal of Medical Entomology* 39(1): 4–11.
38 Yang, G. J. et al. (2005), ‘A potential impact of climate change and water resource development on the transmission of Schistosoma japonicum in China’, *Parassitologia* 47(1): 127–34.
39 Beugnet, Frédéric (2011), ‘Mathematical modelling of the impact of climatic conditions in France on Rhipicephalus sanguineus tick activity and density since 1960’, *Geospatial Health* 5(2): 255–63.
40 The Climate Institute (2011), *A Climate of Suffering* (Sydney: The Climate Institute).
41 Strazdins, L. (2011), ‘Climate change and children’s health: likely futures, new inequities?’, *International Public Health Journal*, 2(4): 493–500.
42 Burke, M.B. et al. (2009), ‘Warming increases the risk of civil war in Africa’, *PNAS* 106: 20670–74.
43 Bouma, M.J. et al. (1997), ‘Global assessment of El Niño’s disaster burden’, *The Lancet* 350: 1435–38.

Figure 2: Difference in risk of civil conflict in countries that are and are not affected by El Niño events (1950–2004)



Source: Source: Adapted from Figure 2 in Hsiang et al., 2011 (see note 44)
Note: Civil conflict involving minimum 25 combat deaths

in multi-year droughts. A recent study (see Figure 2) of 175 countries and 234 conflicts between 1950 and 2004 estimates that the chance of civil war breaking out in the subset of 82 countries known to be affected by El Niño events doubled during those warmer spells – an outcome that the research team attributed predominantly to the stresses of crop failure, hunger and consequent predation on neighbours' food stocks.[44]

Migration and displacement

Such climatic drivers as these can also lead to out-migration, including the flight of 'environmental refugees'.[45] That displacement is often into areas where resources are already strained and where the consequent risk of conflict may be greater still.

Climate change, often acting in conjunction with other environmental and demographic stressors, is forecast to cause large numbers of people to move (voluntary migration) or to be displaced during the coming three to four decades. Estimates vary from tens of millions to 250 million people moving or being displaced.[46] Such estimates are based on broad assessments of likely climatic-environmental circumstances, rather than on systematic knowledge of the sensitivity of human movement to particular changes in environmental circumstances. Those estimates do not incorporate projected demographic and socioeconomic changes, nor the extent to which future adaptation may offset climate impacts and hence the need to relocate.[47]

The pressures to relocate will usually reflect a chronic and foreseeable decline in food availability, freshwater supplies, living space and arable land, and natural protection from extreme weather events. These climatic-environmental stressors are illustrated in Figure 3.

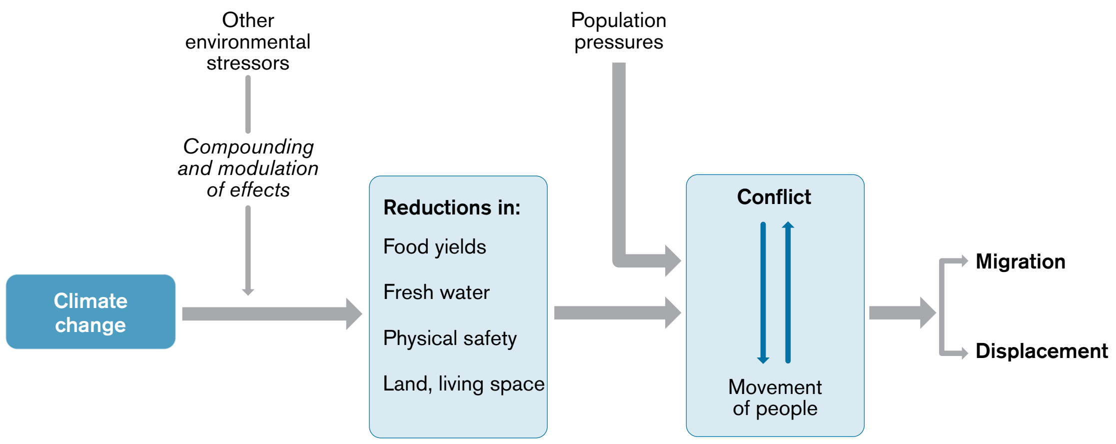
44 Hsiang, S.M. et al. (2011), 'Civil conflicts are associated with the global climate', *Nature* 476: 438–441.

45 McMichael, A.J. et al. (2010), 'Climate change, displacement and health: Risks and responses', in McAdam J. (ed.), *Climate Change and Population Displacement: Multidisciplinary Perspectives* (London: Hart Publishing), pp. 191–219.

46 Myers, N. and Kent, J. (2003), 'New consumers: The influence of affluence on the environment', *PNAS* 100: 4963–68.

47 Barnett, J. and Webber, M. (2010), 'Accommodating Migration to Promote Adaptation to Climate Change', *Background paper to the 2010 World Development Report; World Bank Policy Research Working Paper 5270* (Washington: The World Bank); Asian Development Bank (2011), 'Climate Change and Migration in Asia and the Pacific (draft edition)' (Manila, Philippines: Asian Development Bank).

Figure 3: How climate change can increase risk of tension, conflict and population displacement



Source: Author

Research priorities

To better understand and estimate the range and magnitude of likely health impacts of climate change, more and better research is needed in different populations in three areas:

- Risk assessment;
- Adaptation options and priorities; and
- Mitigation costs and benefits of local action (irrespective of the subsequent global reductions in health risks due to the actual slowing of climate change).

Much current knowledge of climate–health relationships has come from studying short-term associations between climatic events such as heatwaves or El Niño events and health outcomes. However, most of the future risk to health will arise from more sustained changes in climate (often supplemented by acute weather shocks), affecting food yields, infectious disease patterns, safety of settlements, community morale and mental health.

A further limitation in the current evidence base comes from deficiencies in national and regional health information systems, particularly in low-income countries. Since there are often several plausible explanations of changes in observed rates of climate-sensitive diseases, high-quality systematic data are required in order to make assessments.

Further, research findings in a particular population do not necessarily provide a 'one size fits all' evidence base. A broad and varied base of research evidence is therefore needed. Populations in different regions and with different socioeconomic and cultural profiles will vary greatly in susceptibility to various health risks posed by climate change. Communities living in some coastal and low-lying areas will be much more susceptible to coastal flooding and, often, tropical cyclones. Those living in circumpolar regions may experience enforced dietary changes because of shifts in animal migrations and in human access to traditional foods. Meanwhile, vector-borne diseases may display longer annual transmission seasons.

Policy implications

The above review makes clear the many ways in which changes in climatic conditions affect the health of populations. It is also clear from the slow processes and inherent inertia of the climate system, as it responds to past greenhouse gas emissions, that human populations will now inevitably experience changes in climate for many decades. There are a number of particularly important points to note:

- Climate change is proceeding differently and at different rates around the world.
- Some populations and regions are much more vulnerable than others.
- Impacts on health are already becoming apparent in many regions.
- Many of these impacts are widening the health-gap between rich and poor (and will do so increasingly).
- Healthcare systems and public health programmes will come under increasing, and often unfamiliar, demand-stress.
- The economic cost of expanded emergency services and healthcare facilities, expanded surveillance programmes, intensified preventive programmes, and housing and resettling displaced groups will keep growing, potentially to the detriment of other social and economic development goals.
- Population health also has significance as a sentinel measure of environmental sustainability and social progress, and is not merely an asset for economic productivity.
- Unavoidable ongoing climate change means that 'adaptive' strategies to lessen unavoidable risks to health are needed. This will require increased international economic aid, modified global economic processes and knowledge-sharing.
- Greater and clearer understanding of the risks to population health from climate change greatly strengthens the case for urgent and effective international 'mitigation' action on climate change.
- Compensatory actions taken by governments and markets in response to climate change will also contribute to conditions and factors that can both improve and damage human health.

Current economic estimates heavily underestimate the risks that poor health poses to labour and capital. Workers in various heat-exposed workplaces are especially vulnerable.[48] In workforces already near their limit of heat tolerance, a 2°C rise in heat exposure is likely to halve output, largely because of the time required for rest.[49] Detailed analyses of the consequences of climate change for work productivity and economic growth are currently being carried out, using heat exposure mapping. This indicates the serious heat/health/productivity problems in South Asia, Australia and the southern United States.[50] There will also be productivity losses arising from increased rates of infectious diseases and mental health disorders.

'If food shortages and under-nutrition emerge, freshwater supplies dwindle, various infectious diseases begin to spread, and extreme weather patterns increase markedly, then human society is on a non-sustainable path'

The capacity of health systems to respond to direct and indirect health risks and impacts will be tested. Adverse health impacts are not mere collateral damage, to be diagnosed or treated through health systems. Rather, if food shortages and under-nutrition emerge, freshwater supplies dwindle, various infectious diseases begin to spread, and extreme weather patterns increase markedly, then human society is on a non-sustainable path. The result is population decline, die-off and strife.

Individual good health is a human right and a social expectation. However, the good health of a population is also a key, integrative measure of how well a society

48 Kjellstrom, T. (2009), 'Climate change, direct heat exposure, health and well-being in low and middle income countries', *Global Health Action 2, Special Volume*, DOI: 10.3402/gha.v2i0.1958.

49 Kjellstrom, T. et al. (2009), 'Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change', *Global Health Action 2*, *Special Volume*, pp. 46–51.

50 Hyatt, O. et al. (2010), 'Regional maps of occupational heat exposure: past, present and potential future', *Global Health Action 3*, DOI: 10.3402/gha.v3i0.5715.

is managing its biophysical and social environments. The Rio+20 conference provides an opportunity to place population health as a 'sentinel' marker of environmental sustainability.

From policy to action

Mitigation – a double dividend for population health

The slowing or halting of climate change is a huge, urgent and internationally shared responsibility. From a human health perspective, it represents the ultimate prevention of current and future risks to health. A compelling reason for taking early and effective mitigation action is to avert the great and growing risks to human health that will arise from climate change.

Meanwhile, there is an important, but as yet less well understood, positive health-related incentive for governments and societies. In those populations that take mainstream mitigating action there will be near- to medium-term and mostly localized health gains. Good examples are the potential 'health co-benefits' from greenhouse gas emission reduction policies in the domains of transport, built environment, electricity generation and agriculture. Health benefits would result from less polluted urban air, increased levels of physical activity, better-insulated housing and reduced intake of high-energy, high-fat animal foods.[51]

For example, around 2.5 billion people in low-income countries use traditional biomass or solid-fuel combustion for household cooking and heating. Some of the resulting airborne pollutants, including methane and black carbon, contribute to climate change. In poor unventilated housing, widespread in many rural areas, the high levels of indoor air pollution are a major source of premature child deaths and serious illnesses in women and children, especially from pneumonia, chronic lung disease and lung cancer. Great gains in public health could therefore be achieved by increasing householder access to higher-grade energy sources. The installation of improved cooking stoves can serve as both climate change mitigation and family health protection.

As a stimulus to mitigation policy-making, research-based evaluation of potential health co-benefits will further highlight this important 'positive' message: the mitigation of climate change can provide a double dividend to population health along with the associated savings to the healthcare system. Indeed, it is unlikely that, in the absence of policies to promote low-carbon development strategies, priority health problems such as obesity, diabetes and those related to air pollution exposure can be addressed effectively. In some cases much or all of the extra cost involved in low-carbon strategies could be offset as a result of the ensuing health and environmental benefits.

Adaptation – early action to manage unavoidable risks

Human-induced climate change is already occurring, and more warming is 'locked in', though not yet registering on the thermometer. Related risks to human health are therefore unavoidable, and adaptation strategies are needed to lessen the risks to safety, health and survival.

Low-income countries are generally at greater risk from climate change, particularly in its early stages. Many will need substantial assistance in developing, assessing and then extending/modifying their adaptive strategies to lessen the risks to health. A wide range of risks should be considered, such as physical injury from coastal weather extremes; drowning, food shortages and mental health disorders from inland flooding; declines or losses in local food yields; exposure to extremes of temperature; and the spread of infectious diseases.

Adaptation strategies should take account of existing health and socio-economic disparities and disadvantage. The portfolio of adaptations should also achieve a balance between quick-win interventions and far-sighted climate-proofing interventions – e.g. in urban planning, housing design and sustainable food systems – most of which are desirable even without considering climate change. Adaptation strategies should be evaluated to determine effectiveness and, usually, cost-effectiveness. For example, early warning systems to alert communities, especially

51 Haines, A. et al. (2009), 'Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers', *The Lancet* 374: 2104–14.

elderly people and their carers, to impending heatwaves should be evaluated in a range of cities, including mega-cities in low-income countries.

There is also self-interest for high-income, lower-risk populations. If adaptive strategies are absent or ineffective in higher-risk populations, and if the experience and expectation of loss, deprivation and increased disadvantage were to grow, then tension and conflict could result more easily. So, too, could the flow of 'environmental and climate' refugees.

Conclusion

The environmental and social impacts of climate change will mostly act to the detriment of human safety, health and survival. At the same time, a low-carbon economy would make a major contribution to addressing many of the priority health conditions that are currently overburdening health systems.

In most countries, the health sector has been slow to recognize the serious implications of climate change for population health and for the healthcare system. That partly reflects the misleading, individual-focused model of 'health' and its causation that prevails in many modern societies. That model, viewing individuals as free agents responsible for their own health-related actions, impedes recognition that a *population*'s way of living and its collective environmental conditions are the prime determinants of the rates and patterns of health and disease within that population. The health sector must therefore further widen its field of vision in order to play a substantive role in the policy discourse, to forge effective links with other sectors of government and to assist in arresting this source of risk to the health of present and future generations.

> 'Viewing individuals as free agents responsible for their own health-related actions impedes recognition that a *population*'s way of living and its … environmental conditions are the prime determinants of … health and disease'

The overloading of Earth's natural systems carries the seeds of wider-ranging risk. This includes the risk that human-induced climate change will cause much of the hard-won advance in social and economic development, in international cooperation, and in the reduction of illnesses and deaths to stall, perhaps even unravel. If climate change causes increases in poor health, child deaths, hardship, displacement and conflict, and if it causes geopolitical instability and international tensions, then the security of global health and the health of global security will be at great risk.

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