

This pdf contains:

Kovats, S. and S. Lloyd 2009. "Population, Climate and Health." Pp 164-175 in: *Population Dynamics and Climate Change*, edited by J.M.Guzmán, G. Martine, G. McGranahan, D. Schensul and C. Tacoli. New York: UNFPA; London: IIED.

The contents of the full book can be found here:

<https://www.unfpa.org/public/publications/pid/4500>

This pdf was downloaded from www.ied.org

Population, Climate and Health

*Sari Kovats
Simon Lloyd*

Introduction

Global climate change will have important implications for human population health. It is one of the emerging set of global environmental changes that are already affecting human population health and will increasingly do so in the future (ESSP, 2006). Climate change does not exist as a separate, single exposure, but consists of a range of exposures that are relevant for human health (McMichael et al., 2006). Climate change will exacerbate many of the current important environmental determinants of disease. Some climate and weather factors act directly and are relatively well understood—such as the health effects of heat waves or the physical and mental consequences of floods. Other health effects are mediated by climate-sensitive biological processes, such as changes in infectious disease transmission or crop yields. Climate is ultimately the determinant of food and water availability and the distribution of vector-borne diseases. Climate-related decreases in food and water supplies are potentially responsible for the largest future burden of disease due to climate change (Campbell-Lendrum and Woodruff, 2006). But such impacts are also the most uncertain to foresee because they are contingent on future social, economic, political and population factors.

There is now a wealth of evidence regarding changes in climate and environment due to anthropogenic climate change. The Intergovernmental Panel on Climate Change (IPCC) published its Fourth Assessment Report in 2007, which included a global assessment on the impacts of climate change on human health (Confalonieri et al., 2007). The conclusion of the health chapter was that:

. . . the health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrhoeal diseases; increased diseases due to higher concentrations of ground-level ozone related to climate change; and the altered spatial distribution of some infectious diseases (IPCC, 2007).

The scientific evidence base is still evolving. Currently, the main evidence for the impacts of climate change is based on large-scale modelling of bio-geophysical systems. There has been a lack of evidence about the effects on human systems

and how population and environmental factors interact to increase the burden of disease.

Evidence for current sensitivities of a population's health to weather and climate is based on epidemiological studies. The current state of knowledge on the health effects of weather and climate variability from epidemiological studies is summarized in Table 10.1. There is a need to infer the potential health effects from current and past climate variability in order to account for the greater spatial and temporal scales appropriate to climate change. Such analogue studies are useful for investigating the impact of larger-scale climate effects on health by looking at past climate events, such as droughts. An example is the demonstrated effects of the global climate phenomenon the El Nino-Southern Oscillation (ENSO) on malaria (Kovats et al., 2003).

For assessing the future impacts of climate change, a range of health-impact models need to be developed for specific diseases (e.g., malaria) and environmental exposures (e.g., heat waves). Health impact assessments of climate change should incorporate the environmental, social and human dimensions (Ebi, et al., 2005; Parry et al., 2007). Projections of future impacts should also include a consideration of multiple exposures on specific population groups. Many of the anti-

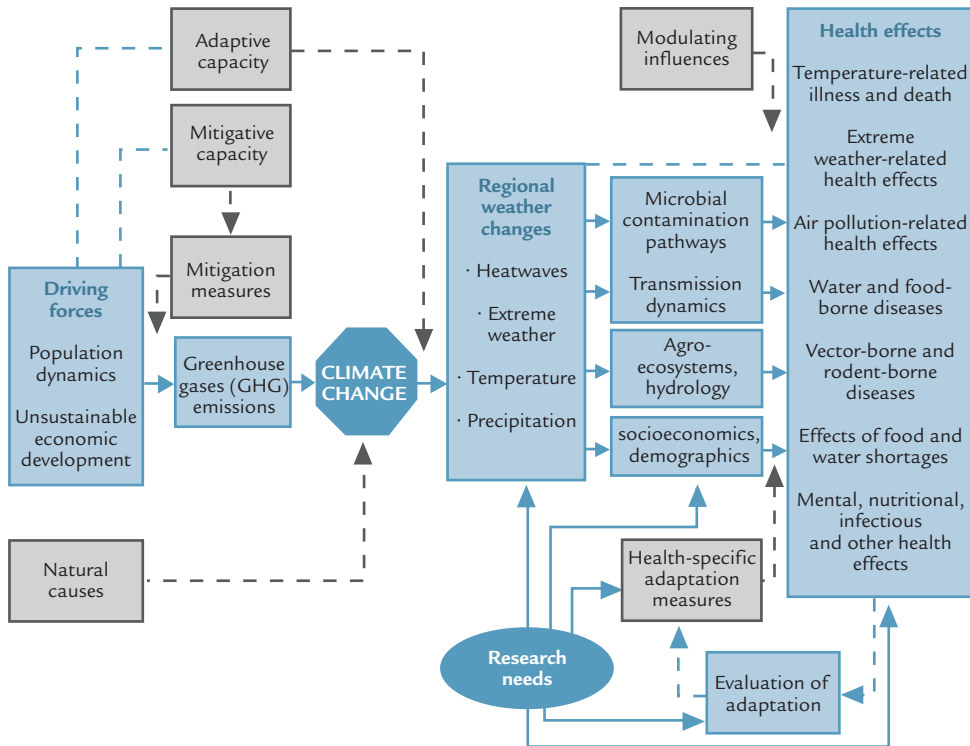
Table 10.1: Current State of Knowledge on the Impacts of Weather on Health Outcomes

Category of health outcome	Known effects of weather and climate variability
Heat stress	<ul style="list-style-type: none"> • Deaths from cardio-respiratory disease increase with high and low temperatures; • Heat-related illness and death due to heat waves.
Air pollution-related mortality and morbidity	<ul style="list-style-type: none"> • Weather affects air pollutant concentrations; • Weather affects distribution, seasonality and production of aeroallergens.
Health impacts of weather disasters	<ul style="list-style-type: none"> • Floods, landslides and windstorms cause direct effects (deaths and injuries) and indirect effects (infectious disease, loss of food supplies, long-term psychological morbidity).
Mosquito-borne diseases, tick-borne diseases (e.g. malaria, dengue)	<ul style="list-style-type: none"> • Higher temperatures reduce the development time of pathogens in vectors and increase potential transmission to humans; • Vector species require specific climatic conditions (temperature, humidity) to be sufficiently abundant to maintain transmission.
Water-/food-borne diseases	<ul style="list-style-type: none"> • Survival of important bacterial pathogens is related to temperature; • Extreme rainfall can affect the transport of disease organisms into the water supply. Outbreaks of water-borne disease have been associated with contamination caused by heavy rainfall and flooding, associated with inadequate sanitation; • Increases in drought conditions may affect water availability and water quality (chemical and microbiological load) due to extreme low flows.

Source: Adapted from: Kovats and Akhtar, 2008.

pated effects of climate change will not be disease-specific, but address broader determinants of health that are not readily quantified, such as poverty, displacement and access to food or water (Woodward et al., 1998). The literature is still, however, heavily biased towards quantitative assessments within prescribed scenarios for easily measured (and costed) outcomes (Watkiss and Downing, 2008).

Figure 10.1: Pathways by which Climate Change may affect Human Health



Source: McMichael et al., 2003.

This chapter provides a brief overview of the current state of knowledge on the potential impacts of climate change on human health. Areas will be identified where population factors are an important determinant of the risk posed by climate change on health in relation to food, water, extreme weather (including heat waves, floods) and vector-borne disease. Studies that have looked at migration (or population movement) in relation to climate change or human health will not be reviewed.

Food and Malnutrition

Hunger and malnutrition are widespread, and it is anticipated that climate change will exacerbate this by further reducing global food security. Presently, there are close to one billion people with insufficient calorie intake (FAO, 2008), and one third of the burden of disease in young children is attributable to malnutrition

(Black et al., 2008). Future impacts will depend on the trajectories of a number of factors, including the magnitude of climate change, the size of the population, their income levels and the environment in which they live, as well as (technological) developments in agriculture.

While climate change is likely to affect crop productivity, food security—and the relationship between food and health—is governed by many factors. The key determinants are: availability (the adequacy of food production and supply), stability (the consistency of these food supplies over time), accessibility (the accessibility of food to the population at large) and utility (the health of those consuming the food, and their ability to benefit from the energy and nutrients in the food they consume). Compromising any of these elements could lead to increased levels of malnutrition and poor health; future change in mean climate, extreme weather events and population size and distribution are likely to impact on each of them. However, modelling the elements of food security simultaneously is difficult, and, to date, no quantitative studies have taken account of all of them. Consequently, assessments of future hunger and malnutrition only capture a part of the picture, despite the use of specific and plausible climate and population scenarios.

A number of studies have modelled crop productivity (i.e., addressed ‘availability’) under various climate and population scenarios (see Parry et al., 2007, for an overview), and two recent papers illustrate the potential threat posed to populations with already high levels of malnutrition. Lobell et al. (2008) used statistical models for a range of crops grown in 12 food insecure regions to estimate productivity in 2030. They found that, in the near future, changes in temperature and rainfall are likely to reduce the crop yields of various food sources, particularly in South Asia and Southern Africa (Lobell et al., 2008). Battisti and Naylor (2009) looked to the end of the 21st century and suggest that, by that time, there is a 90 per cent probability that growing-season temperature will exceed even the most extreme temperatures seen during 1900 to 2006. This could severely reduce crop productivity and may place three billion people, most of whom depend on agriculture for their livelihood, at risk. The areas expected to be most affected are tropical and sub-tropical Africa and Asia and parts of South, Central and North America and the Middle East (Battisti and Naylor, 2009).

Where food is grown (‘availability’) may not be where it is consumed (‘access’). The global trade in food is a determinant of access and relates to cost and the ability of populations to purchase food. While climate change is estimated to increase the population at ‘risk of hunger’ due to reduced crop productivity, socio-economic factors will have a far greater impact. In scenarios in which population growth is decreasing and there is strong economic growth, the models suggest that hunger could decrease by more than 75 per cent from current levels by 2080 (Schmidhuber and Tubiello, 2007). In addition—driven almost entirely by socio-economic factors but contingent on assumptions made within scenarios—the region with the greatest number of hungry people is expected to shift from South Asia to sub-Saharan Africa by the 2080s. Of course, despite their relative importance, development pathways will not occur independently of climate change;

increases in wealth, narrowly defined, could come at the expense of significantly increased greenhouse gas emissions which would result in greater impacts of climate change on food production.

None of the above studies include impacts of extreme weather events, such as droughts, or ‘surprise’ events, such as pest invasions (‘stability’). Hence, the impact of climate change, which has the potential to increase both of these, could be reasonably expected to be greater than the models suggest. Furthermore, the effects of a lack of food are magnified by other factors such as diarrhoea prevalence (‘utility’). If a population lacks improved water sources and sanitation which result in high rates of diarrhoea, there will be more malnutrition associated with a given level of food consumption. A multi-country analysis found that approximately a quarter of malnutrition in children aged two could be attributed to having had five or more episodes of diarrhoea (Checkley et al., 2008).

Overall, future hunger and malnutrition will be driven by a range of influences, which will, in turn, be related to both climate and population changes. Other factors, such as governance that ensures equitable access to food, will be critical.

Water and Health

Climate is a key determinant of water availability. Surface water availability depends on the timing and volume of precipitation. The current burden of disease as a result of inadequate access to improved water sources and sanitation has long been recognized, particularly the very high rates of infant mortality in deprived urban areas (Kosek et al., 2003). There are clear social and economic reasons for the lack of access to improved water at the household level. However, populations in both high- and low-income countries have experienced failures in supply due to extreme droughts. It is also known that access to water is not equally distributed within cities, and any reductions in supply are likely to have a greater impact on impoverished populations.

Climate impact assessments are often conducted at the river catchment level and converted to water availability per capita or withdrawal-to-resource ratio. Such indicators are useful to some extent, but they provide no information on the level of access to water, the quality of water or any differences between rural or urban areas. Climate change is likely to cause a decline in environmental water resource availability in certain areas, where water resource management is poor or non-existent. This will have a negative impact on water availability at the household level.

The impact of climate change on water availability is likely to be one of the most significant for the health of populations. However, due to the complexity of the factors that determine access to clean water (social, political, environmental), the impacts on health are not well addressed in the climate impacts literature. Although disease rates can be reduced very cost effectively by improvements in hygiene behaviour, such improvements require access to sufficient quantities of water. In one study, interventions to improve water quality failed to deliver a significant reduction in diarrhoeal disease in places where water availability was limited

(Esrey et al., 1991). As discussed below, heavy rainfall and flooding are also important issues for environmental health in urban areas (Kovats and Akhtar, 2008).

Emerging Infectious Disease

Many infectious diseases of animals, humans and plants will be affected by climate change (Brownlie et al., 2006a), and diseases transmitted by cold-blooded vectors will be the most susceptible to climate effects. According to the United Kingdom Foresight review, future expectations of infectious disease are based on an understanding that the majority of 'emerging and re-emerging' human infectious diseases originate in animal sources. Since these animals are likely to face continued incursions into their natural habitat, trade for meat and exotic commodities, as well as their presence as pets, the trend of one or two new human pathogens identified each year is expected to persist (Brownlie et al., 2006b). Climate-change impacts should therefore also be seen in the context of these other important drivers of the emergence of infectious disease and the large changes that are already occurring.

The global burden of vector-borne diseases, especially malaria, remains high (Thomson et al., 2006). Climate factors affect both malaria-carrying mosquito vectors and malaria parasite development rates. Although the overall impact of climate change is uncertain, it is likely to facilitate vector expansion to higher altitudes in highland areas surrounded by endemic transmission (Tanser et al., 2003). The East African highlands are densely populated and therefore potentially at an increased risk of malaria due to climate warming. Malaria epidemics are of particular concern as they occur in populations that lack partial or full immunity to the disease and thus experience high mortality rates across all age groups (Cox and Abeku, 2007).

Examples of evidence for climate effects on other infectious diseases include (IRI, 2005):

- **Meningitis:** Occurrence in the Sahelian dry season is associated with increases in temperature and decreases in humidity and is related to dust. Epidemics occur in environmentally suitable districts during the dry season and end with the first rains. There is a moderately strong relationship between climate and outbreaks of meningitis that is not well understood.
- **Cholera:** Outbreaks are associated with increases in sea surface temperatures (related to ENSO), in addition to poor sanitation and hygiene behaviour. The association between climate and cholera outbreaks is strong in the coastal regions of Bangladesh.
- **Rift Valley Fever:** Epidemics (animal and human) are related to short-term increases in rainfall. Cold weather is associated with the end of epidemics. Rift Valley Fever is moderately sensitive to climate variability.

- **Leishmaniasis:** is associated with an increase in temperature and rainfall. Outbreaks of leishmaniasis show a moderate variability based on climate.

Although vector-borne diseases are strongly affected by rainfall and temperature, which can trigger outbreaks, the longer-term impacts on these diseases due to climate change is less clear. The effects will depend on the current distribution of the disease (many diseases are well within the climate-limits) and the capacity of countries to control the infection over the next decades.

Flooding and Disasters

Flooding and tropical cyclones are the most common ‘natural’ disasters, accounting for 40 per cent of the 1,062 recorded disasters between 2004 and 2008. Each year, around 120 million people are exposed to tropical cyclones and storm surges, which caused an estimated 250,000 deaths between 1980 and 2000 (Nicholls et al., 2007). Single events can be devastating: In Bangladesh, tropical cyclones in 1970 and 1991 caused 300,000 and 140,000 deaths, respectively (Kron, 2005). The impact of an event, however, is greatly modified by population vulnerability. For example, similar numbers of people are exposed to tropical cyclones in Japan and the Philippines each year (22.5 million and 16 million, respectively), but the death toll in the Philippines is 17 times higher than that in Japan (UNISDR, 2009). Considering low-income countries as a group, the relative mortality risk is close to 200 times higher than in countries of the Organisation for Economic Co-operation and Development (OECD) (UNISDR, 2009). These figures highlight the influence of both climate and population factors on health impacts.

Future trajectories of the population at risk of flooding have been developed using a global coastal flood model (Nicholls, 2004). The model was run for the climate and socio-economic scenarios developed by the IPCC for the *Special Report on Emissions Scenarios* (SRES) (IPCC, 2000). When socio-economic scenarios for a world with declining population growth and robust economic development are considered without climate change, the numbers at risk of flooding increase until the 2020s and then decline significantly by the 2080s. The initial increase in numbers at risk is driven by the model’s assumptions that coastal populations will grow at twice the rate of the whole population and that, while increasing wealth will lead to improved flood defences, the time it takes to build new coastal defences is approximately 30 years. In socio-economic scenarios with high population growth and lower economic growth, the numbers at risk of flooding continue to rise beyond the 2080s.

When sea level rise due to climate change is included in the model, significant additional impacts are not evident until the 2080s, when, depending on the scenario used, between 2 and 50 million additional people are estimated to be at risk. The model does not account for the possibility of an increase in the frequency and intensity of tropical cyclones and storm surges, which have the potential to greatly increase flood risk attributable to climate change. Overall, the model suggests that the population size, the areas in which they live, their wealth (in terms of ability

to build flood defences) and the increased risk of flooding attributable to climate change will all be critical determinants of future flood risk.

Heat Waves

An increase in heat waves is one of the most certain impacts of climate change. All populations are affected by extremes of temperatures. Epidemiological studies have mostly been undertaken in populations in temperate climates, where mortality is shown to increase in hot and cold weather. Heat mortality risk varies by age and with other social and environmental factors (Kovats and Hajat, 2008). The majority of European studies have shown that women are more at risk of dying in a heat wave. There may be some physiological reasons for an increased risk in elderly women (Burse, 1979; Havenith, 2005), but social factors are also important. Elderly men are more at risk from heat waves than women in the United States, and this was particularly apparent in the Chicago heat wave in 1995 (Semenza et al., 1996; Whitman et al., 1997).

In addition to the 'natural' patterns of ageing (or senescence) on homeostatic mechanisms, several medical conditions increase vulnerability to heat stress (Stafoggia et al., 2006; Schwartz, 2005). Many deaths that are 'attributed' to heat do not result from heat stroke or are even in persons that exhibit the clinical signs of heat stress. It is likely that there are several mechanisms by which a person may succumb during a heat wave, as the environmental temperature places extra strain on the body. If the exposure to heat is severe enough, even healthy people will succumb to heat stroke.

Climate change is likely to increase the number of heat-related deaths in temperate populations. Less is known about heat effects in tropical or sub-tropical regions. A main uncertainty in estimating the future impact of climate change on heat-related mortality is the extent to which, even without specific adaptation strategies, physiological adaptation and factors such as behavioural changes in hot weather will reduce impacts in the general population. Physiological acclimatization to hot environments can occur over a few days, and this can explain why the impact of the first heat wave on mortality is often greater than that of subsequent heat waves during a single summer. The rate at which infrastructural changes will take place is likely to be much slower. Neither the magnitude nor the time course of the various modifying factors can be predicted with any confidence. It is clear that preventive measures will be needed to counter the substantial initial adverse effects of heat, and long-term changes are required in housing and urban infrastructure (Kovats and Koppe, 2005).

Implications for Adaptation

The implementation of adaptation strategies in relation to health is only just beginning. The WHO 61st World Health Assembly 2008, held in Geneva, 19-24 May 2008, called on Member States for more action on protecting health from

the effects climate change (WHO, 2008; McMichael et al., 2008). Countries are, in fact, mandated under the United Nations Framework Convention on Climate Change (UNFCCC) to undertake national assessments of adaptation and vulnerability as part of their National Communications. Assessments of adaptation in the least-developed countries have been supported by the National Adaptation Programmes of Action (NAPA) process. Yet health is generally not well addressed in these reports. A few countries have undertaken more detailed health impact assessments outside the UNFCCC framework, for example, the United Kingdom (Department of Health and Health Protection Agency, 2008), Canada (Health Canada, 2008) and Portugal (Casimiro and Calheiros, 2002).

Estimating the potential impacts of climate change on specific health outcomes and providing information for decision makers is made difficult by the complexity of the relationships among environment, population and health. Future population trends and demographic processes will play more than a modifying role in this; they will be key factors in determining which health impacts are seen and where. The rate of growth of coastal cities in areas prone to tropical cyclones, and the level of protection put in place, could greatly influence future mortality. The diversity of livelihoods will influence the vulnerability of rural populations to malnutrition when drought causes crop failure. Infrastructure, and the distribution of access to it, is likely to affect whether the potential for greater spread of diarrhoea-causing pathogens in warmer climates leads to increased child mortality. In addition, population health itself is not only an outcome, it is also a vulnerability: A chronically malnourished population will be particularly susceptible to acute food shortages due to extreme weather events.

Protecting and improving human population health requires new research on climate-health links, as well as improved methods to guide adaptation strategies. To identify future health threats and the populations likely to be affected by them, epidemiological methods and modelling strategies—which have conventionally focused on less complex risk-outcome structures—need to be further developed and, in particular, applied in low-income settings. In order for such research to be used to develop policy, it should, where possible, specifically consider the influence of socio-economic and demographic factors. It is often possible to include these when assessing the past and present. However, when considering future impacts, the application of such findings is difficult, as quantitative descriptions of plausible future socio-economic and demographic conditions are generally limited to GDP and to population in terms of numbers and age-stratification.

Means to overcome these limitations include the development of scenarios with more detailed quantitative descriptions of plausible future worlds and the modification of methods for assessing the means of adaptation in the face of particular health threats. Additionally, methods of assessing and characterizing uncertainties in health assessments need to be further developed and should focus particularly on ensuring that the characterization is useful to policymakers. Given that many adaptation strategies have long lead times, it is critical to ensure that the

uncertainties inherent in the still developing field of climate-health research do not prevent appropriate actions from being taken.

Climate change is a unique health threat in that it will affect all populations and requires consideration of extended time frames. In the near term, many of the mechanisms by which health will be affected are known—although the magnitude of the impacts and effectiveness of prevention are highly uncertain. There are likely to be many changes that are unanticipated involving ecological shifts or emerging infections. Under the higher projections of warming (more than 2-3°C above pre-industrial climate), the uncertainty is greatly increased (Kovats et al., 2005). This rate of change is unprecedented for humans and has unknown implications.

References

- Battisti, D. S., and R. S. Naylor. 2009. "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat." *Science* 323(5911): 240-244.
- Black, R. E., et al. 2008. "Maternal and Child Undernutrition: Global and Regional Exposures and Health Consequences." *The Lancet* 371(9608): 243-260.
- Brownlie, J., et al. 2006a. *Foresight: Infectious Diseases: Preparing for the Future: Future Threats*. London: Office of Science and Innovation.
- _____. 2006b. "Executive Summary." In: *Foresight: Infectious Diseases: Preparing for the Future: Future Threats*, by J. Brownlie et al. London: Office of Science and Innovation
- Burse, R. L. 1979. "Sex Differences in Human Thermoregulatory Response to Heat and Cold Stress." *Human Factors* 21(6): 687-699.
- Campbell-Lendrum, D., and R. E. Woodruff. 2006. "Comparative Risk Assessment of the Burden of Disease from Climate Change." *Environmental Health Perspectives* 114(12): 1935-1941.
- Casimiro, E., and J. M. Calheiros. 2002. "Human Health." Pp. 241-300 in: *Climate Change in Portugal: Scenarios, Impacts, and Adaptation Measures: SIAM Project*, edited by F. D. Santos, K. Forbes, and R. Moita, 2002. Lisbon: Portugal Gradiva.
- Checkley, W., et al. 2008. "Childhood Malnutrition and Infection Network: Multi-country Analysis of the Effects of Diarrhoea on Childhood Stunting." *International Journal of Epidemiology* 37(4): 816-830.
- Confalonieri, U., et al. 2007. "Human Health." Pp. 391-431 in: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by M. L. Parry et al. 2007. Cambridge: Cambridge University Press.
- Cox, J., and T. A. Abeku. 2007. "Early Warning Systems for Malaria in Africa: From Blueprint to Practice." *Trends in Parasitology* 23(6): 243-246.
- Department of Health and Health Protection Agency. 2008. *Health Effects of Climate Change in the UK 2008: An Update of the Department of Health Report 2001/2002*. London: Department of Health and Health Protection Agency.
- Earth System Science Partnership (ESSP). 2006. *Global Environmental Change and Human Health: Science Plan and Implementation Strategy*. ESSP Report. No. 4.
- Ebi, K. L., N. D. Lewis, and C. F. Corvalán. 2005. *Climate Variability and Change and Their Health Effects in Small Island States: Information for Adaptation Planning in the Health Sector*. Geneva: World Health Organization.
- Esrey, S. A., et al. 1991. "Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Trachoma." *Bulletin of the World Health Organization* 69(5): 609-621.

- Food and Agriculture Organization of the United Nations (FAO). 2008. *The State of Food Insecurity in the World 2008*. Rome: FAO.
- Havenith, G. 2005. "Temperature, Heat Balance, and Climatic Stress." Pp. 70-80 in: *Extreme Weather Events and Public Health Responses*, edited by W. Kirch, B. Menne, and R. Bertolini. 2005. Heidelberg, Germany: Springer-Verlag.
- Health Canada. 2008. *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity*. Toronto: Health Canada.
- Intergovernmental Panel on Climate Change (IPCC). 2000. *Emissions Scenarios: Summary for Policymakers*. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. New York, N. Y.: Cambridge University Press.
- _____. 2007. "Summary for Policymakers." Pp. 7-22 in: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by M. L. Parry, et al. Cambridge: Cambridge University Press.
- International Research Institute for Climate Prediction (IRI). 2005. *Sustainable Development in Africa: Is the Climate Right?* IRI Position Paper. IRI Technical Report. No. IRI-TR/05/01. New York, N. Y.: IRI.
- Kosek, M., C. Bern, and R. L. Guerrant. 2003. "The Global Burden of Diarrhoeal Disease, as Estimated from Studies Published between 1992 and 2000." *Bulletin of the World Health Organization* 81(3): 197-204.
- Kovats, R. S., and R. Akhtar. 2008. "Climate, Climate Change and Health in Asian Cities." *Environment and Urbanization* 20(1): 165-175.
- Kovats, R. S., et al. 2003. "El Nino and Health." *The Lancet* 362(9394): 1481-1489.
- Kovats, R. S., D. Campbell-Lendrum, and F. Matthies. 2005. "Climate Change and Human Health: Estimating Avoidable Mortality and Morbidity." *Risk Analysis* 25(6): 1409-1418.
- Kovats, R. S., and S. Hajat. 2008. "Heat Stress and Public Health: A Critical Review." *Annual Review of Public Health* 29: 41-55.
- Kovats, R. S., and C. Koppe. 2005. "Heatwaves: Past and Future Impacts on Health." Pp. 136-160 in: *Integration of Public Health with Adaptation to Climate Change: Lessons Learned and New Directions*, edited by K. L. Ebi, J. Smith, and I. Burton. 2005. Lisse, The Netherlands: Taylor and Francis Group.
- Lobell, D. B., et al. 2008. "Prioritizing Climate Change Adaptation Needs for Food Security in 2030." *Science* 319(5863): 607-610.
- McMichael, A. J., et al. (eds.). 2003. *Climate Change and Health: Risks and Responses*. Geneva: WHO.
- McMichael, A. J., M. Neira, and D. L. Heymann. 2008. "Commentary: World Health Assembly 2008: Climate Change and Health." *The Lancet*. 371(9628): 1895-1896.
- McMichael, A. J., R. E. Woodruff, and S. Hales. 2006. "Climate Change and Human Health: Present and Future Risks." *The Lancet* 367(9513): 859-869.
- Nicholls, R. J. 2004. "Coastal Flooding and Wetland Loss: Changes under the SRES Climate and Socio-economic Scenarios." *Global Environmental Change* 14(1): 69-86.
- Nicholls, R. J., et al. 2007. "Coastal Systems and Low-lying Areas." Pp. 315-356 in: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by M. L. Parry, et al. Cambridge: Cambridge University Press.
- Parry, M. L., et al. 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: Cambridge University Press.
- Schmidhuber, J., and F. N. Tubiello. 2007. "Global Food Security under Climate Change." *Proceedings of the National Academy of Sciences* 104(50): 19703-19708.

- Schwartz, J. 2005. "Who is Sensitive to Extremes of Temperature: A Case-only Analysis." *Epidemiology* 16(1): 67-72.
- Semenza, J. C., et al. 1996. "Heat-related Deaths during the July 1995 Heat Wave in Chicago." *New England Journal of Medicine* 335(2): 84-90.
- Stafoggia, M., et al. 2006. "Vulnerability to Heat-related Mortality: A Multi-City Population-based, Case-crossover Analysis." *Epidemiology* 17(3): 315-323.
- Tanser, F. C., B. Sharp, and D. Le Sueur. 2003. "Potential Effect of Climate Change on Malaria Transmission in Africa." *The Lancet* 362(9398): 1792-1798.
- Thomson, M. C., et al. 2006. "Malaria Early Warnings based on Seasonal Climate Forecasts from Multi-model Ensembles." *Nature* 439(7076): 576-579.
- United Nations International Strategy for Disease Reduction (UNISDR). 2009. "Climate Change and Disaster Risks. ISDR Recommendations for Action Now and Post-Kyoto." Geneva: UNISDR.
- Watkiss, P., and T. E. Downing. 2008. "The Social Cost of Carbon: Valuation Estimates and Their Use in UK Policy." *Integrated Assessment* 8(1).
- Whitman, S., et al. 1997. "Mortality in Chicago Attributed to the July 1995 Heat Wave." *American Journal of Public Health* 87(9): 1515-1518.
- Woodward, A., S. Hales, and P. Weinstein. 1998. "Climate Change and Human Health in the Asia Pacific Region: Who will be the Most Vulnerable?" *Climate Research* 11(1): 31-38.
- World Health Organization (WHO). 2008. "WHO Executive Board: Resolution: Climate Change and Health" (EB122.R4, 1-3), 122nd Session. Geneva, WHO.