The Global Burden of Disease due to climate change: quantifying the benefits of stabilization for human health

D Campbell-Lendrum, World Health Organization, Protection of the Human Environment (PHE), Geneva
RS Kovats, Centre on Global Change and Health, London School of Hygiene and Tropical Medicine, UK.
AJ McMichael, Australia National University, Canberra
C Corvalan, Protection of the Human Environment (PHE), WHO, Geneva
B Menne, European Centre for Environment and Health, WHO, Rome.
A Pruss-Ustun, Protection of the Human Environment (PHE), WHO, Geneva

Key words:

Health, global burden of disease,

Corresponding author:

R Sari Kovats
Centre for Global Change and Health
London School of Hygiene & Tropical Medicine
Keppel Street
London WC1E 7HT
Tel: 020 7927 2962
Fax: 020 7580 4524
Email: sari.kovats@lshtm.ac.uk

The Global Burden of Disease due to climate change: quantifying the benefits of stabilization for human health

D Campbell-Lendrum, World Health Organization, Protection of the Human Environment (PHE), Geneva
RS Kovats, Centre on Global Change and Health, London School of Hygiene and Tropical Medicine, UK.
AJ McMichael, Australia National University, Canberra
C Corvalan, Protection of the Human Environment (PHE), WHO, Geneva
B Menne, European Centre for Environment and Health, WHO, Rome.
A Pruss-Ustun, Protection of the Human Environment (PHE), WHO, Geneva

Abstract

Climate change will have negative impacts on human population health. Impacts for a range of health outcomes have been quantified at global and regional level using standardized methods developed by the World Health Organization. Taking into account both current disease burden and likely future changes, the negative effects of climate change outweigh the positive, with most of the impacts concentrated in developing countries. The greatest impacts are likely to be caused by small proportional changes in diseases that currently have major impacts, such as diarrhoea, malnutrition and vector-borne diseases. By 2030, relative risks are greatest under the business as usual climate scenario. The benefits of stabilization for most health impacts are apparent but subject to high uncertainty. Such quantitative approaches highlight the most important uncertainties in such analyses (particularly related to the role of socioeconomic and other non-climatic factors, which may positively or negatively modify climatic influences), and diseases that have been relatively poorly studied in relation to their likely future importance.

1. Introduction

Climate change was one of the environmental exposures analysed in the World Health Organization's comparative risk assessment of the global burden of disease (GBD)[1-3]. WHO developed comparative risk assessment (CRA) methods to quantify the burden of disease from specific risk factors and to estimate the benefit of realistic interventions that remove or reduce these risk factors. The burden of disease was therefore estimated in relation to three climate scenarios for a range of time periods up to 2030.

Climate change is likely to affect human health through a wide range of mechanisms, through changes in the frequency and intensity of weather extremes, and shifts in distribution of infectious diseases and areas suitable for food production [4].

The 'avoidable burden' at future points in time can be estimated by defining alternative plausible distributions of the risk factor in the study population, and comparing relative risks under each scenario. In this case, the relative risks and associated impact fractions are applied to WHO estimates of future disease burdens, which attempt to take account of the most probable future changes due to climate-independent factors – e.g. improving socioeconomic and disease control conditions. Our analysis therefore attempts to estimate the proportional change that climate change would exert on the disease burden that would otherwise have occurred, if climate had not been affected by human actions. This is different from most published studies of future health impacts, which assume that there will be no changes in disease patterns, other than those caused by climate change.

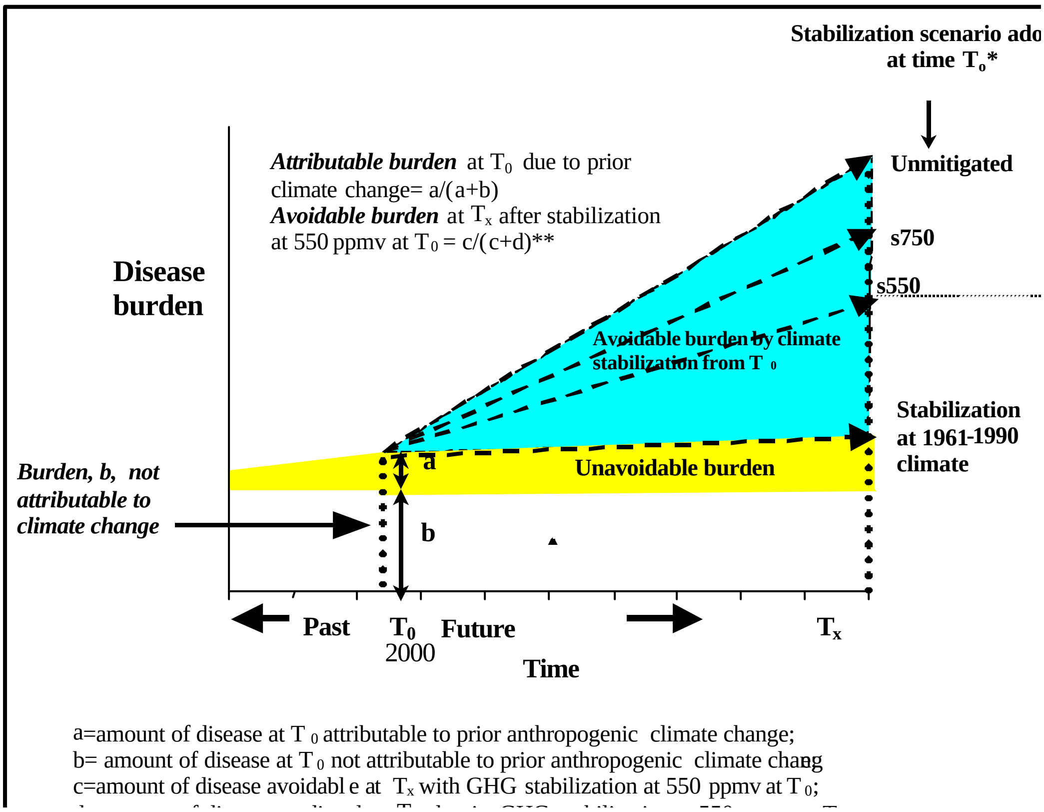

Fig. 1. Defining avoidable burden under climate change in WHO Comparative Risk Assessment.

2. Methods

We generated estimates for the disease burden attributable to climate change for a range of health outcomes and for 14 world regions, at specific time points from 2000 to 2030. We estimated the burden that could be avoided by making plausible reductions in these exposure levels (i.e. greenhouse gas concentrations).

This assessment makes no attempt to estimate the effect of actions taken specifically to adapt to the effects of climate change (e.g. the upgrading of flood defences). The costs and benefits of such actions should be considered separately, and weighed against the predicted impacts if no action is taken.

The health impact models estimate the relative *per capita* incidence of specific health impacts under the different climate scenarios. The size and distribution of current and future populations therefore affect the relative risk estimates (1) when the climate hazard is not evenly geographically distributed throughout the region, or (2) when population is an integral part of the model – e.g. in the risk of hunger model, where population size has an impact on *per capita* food availability.

2.1. Health impact models

Ecological epidemiological studies have been used to quantify the exposure-response relationship for a range of climate sensitive diseases. Time series methods have been developed to estimate the proportion of disease in a population that is attributable to weather (i.e. the short-term variation in meteorological exposures). Strong robust associations have been found between temperature and daily mortality, and between temperature and cases of diarrhoea. The geo-referencing of disease and exposure data have facilitated the investigation of the spatial distribution of many vector borne diseases, such as malaria and dengue which are transmitted by mosquitoes.

The models outputs (relative risks) for each outcome can be converted to deaths or DALYs by region when applied to appropriate population and prevalence/incidence data. A DALY (Disability-

Adjusted Life Year) is the sum of years of life lost due to premature death (taking into account the age of death compared to natural life expectancy) and years of life lived with disability (taking into account the duration of the disease, and weighted by a measure of the severity of disease [5].

Table 1. Health outcomes considered in Global Burden of Disease 2002 exercise.

Class	Mechanism	Outcome
Direct impacts of heat and cold:	Thermal stress due to higher temperatures	Cardiovascular disease deaths
Water-washed, waterborne, and foodborne disease:	Higher temperatures encourage proliferation of bacterial pathogens	Diarrhoea episodes
Vector-borne disease:	Rainfall and temperature affect vector abundance. Temperature affects incubation period of parasite in mosquito	Malaria cases
	Temperature affects incubation period of virus in mosquito	Dengue cases
Natural disasters*:	Increased floods and landslides due to sea level rise and extreme rainfall.	deaths due to unintentional injuries other unintentional injuries (non-fatal)
Risk of malnutrition	Changes in food production and per capita food availability.	non-availability of recommended daily calorie intake

2.2 Climate scenarios

Two stabilization climate scenarios (HadCM2s550 and HadCM2s750) were applied to the health impact models. HadCMs750 is driven by the goal of stabilising atmospheric CO_2 at 750ppmv some time around 2210. HadCM2s550 has an ambitious target of stabilisation at 550ppmv around 2170. A third “business as usual” climate scenario was based on the IPCC emissions scenario IS92a (HadCM3GGa1)[6]. Under the unmitigated emissions climate scenario the world is 4°C warmer by around 2100.

The entire world population is assumed to be exposed to one or other global climate scenario (i.e. exposure prevalence = 100%). Aspects of vulnerability to climate, such as the different impacts associated with an intense precipitation event in developing regions compared to a similarly intense event in a developed region, are dealt with in the calculations of relative risk and attributable burden, rather than exposure prevalence.

2.3 Modifying factors: adaptation and vulnerability

Many factors, such as physiological adaptation and individual and community wealth, will influence both the exposure of individuals and populations to climate hazards and their impacts. For some impact models, simple modifying factors are integrated into the models both for present and future impacts (e.g. people at risk of hunger). Other models incorporate the effects of existing modifiers when defining current climate-disease relationships, such as estimates of the global distribution of malaria based on current climate associations [7]. Such models implicitly capture the *current* modifying effects of socioeconomic and other influences, but do not either (i) separately attribute climate and socioeconomic effects, or (ii) attempt to model *future* changes in these modifiers. Finally, some models make no estimate of such modifying influences in either the present or future: for example models which predict future changes in areas climatically suitable for malaria transmission, and associated populations at risk [8].

To generate consistent estimates, this analysis incorporated:

- Geographic variation in vulnerability to climate, where not already incorporated into the predictive models.
- Future changes in disease rates due to other factors (e.g. decreasing rates of infectious disease due to technological advances/improving socio-economic status), and for changes in population size and age structure (e.g. potentially greater proportion of older people, at higher risk of CVD mortality caused by thermal extremes). Our estimates of relative risks under alternative climate change scenarios have been applied to the WHO projections of disease rates and population size and age structure.

- Assumptions of adaptive capacity, including acclimatization to higher temperatures (cardiovascular disease deaths), and socio-economic development (GDP/per capita threshold applied to increase in diarrhoeal disease)
- Uncertainty estimates describe uncertainties around current exposure-response relationships and around the degree to which these are likely to be maintained in the future. As these have, to date, not been formally modelled, they are generated by qualitative assessment in collaboration with the original modelling group.

The emissions scenarios could be achieved through any of a wide range of development and energy use pathways, and we do not attempt to estimate the secondary effects of GHG mitigation policies on health.

3. Results

The modest climate change that occurred between the mid 1970s and the year 2000 is estimated to have caused the loss of over 150000 lives and 5500000 DALYs per year [3].

The climate change attributable impacts (as defined under a single unmitigated climate scenario) are projected to approximately double by 2020 (Figure 2). The majority of this increased burden of disease will be due to diarrhoeal disease and malnutrition. This is due to the high underlying (baseline) incidence of these diseases at the global level.

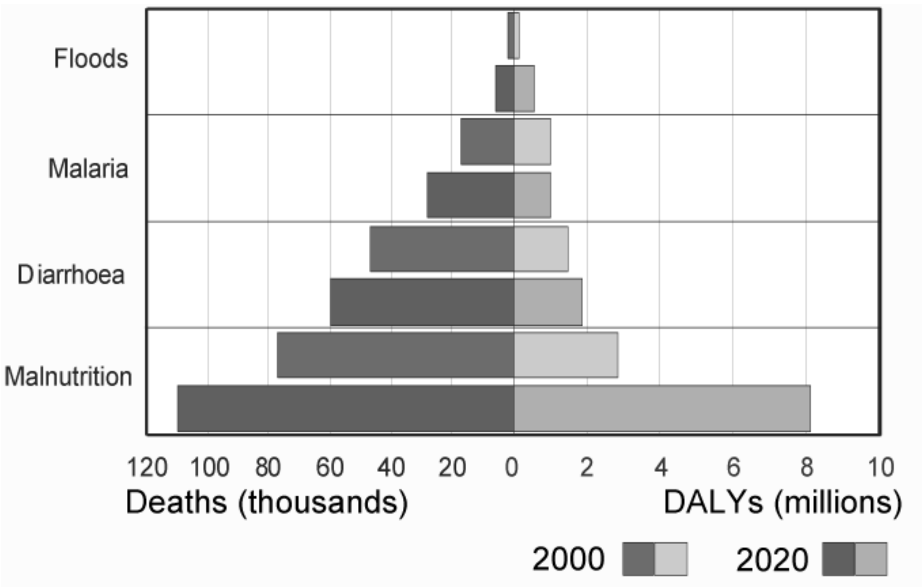

Figure 2. Global burden of deaths and DALYs in 2000 and 2020 attributable to business as usual climate scenario

Table 2 summarises the relative risks for the three climate scenarios in selected WHO regions. Results are presented as relative risks compared to baseline climate, and uncertainty bands (high and low estimates, according to WHO methods). Absolute burdens are dependent on assumptions of population growth and disease incidence and are illustrated in Figure 2.

4. Conclusions

The estimated current and projected future impacts of climate change on human health are largely negative: increased exposures to thermal extremes and weather disasters (deaths and injuries associated with floods), and climate-driven changes to the distribution and incidence of malaria and dengue fever, the incidence of food-borne and water-borne diarrhoea, and yields of agricultural crops. The analyses suggest that climate change will bring some health benefits (lower cold-related mortality and greater crop yields in temperate zones), but that these will be greatly outweighed by increased rates of all other diseases (particularly diseases of childhood, including infectious diseases and malnutrition). The impacts are projected to be heavily concentrated in developing low-latitude countries already experiencing a large burden of disease.

This analysis also clarifies the major knowledge gaps that exist between the most relevant information for decisions on mitigating climate change (i.e. the overall health effects, throughout the globe, over the next century or more), and the information that health scientists are most comfortable in supplying (e.g. the current or past effects of climate on specific diseases, in defined locations). The most important of these gaps are (i) the role of socioeconomic and other non-climatic factors, which may positively or negatively modify climatic influences, and (ii) incomplete, or absence of, quantification for many highly plausible and potentially important health effects of climate change (e.g. from infectious diseases, or arising from the effect of rising sea levels on salination of water supplies and agricultural land, and population displacement).

Table 2. Estimated relative risks of various diseases in 2030, compared to the situation if climate had remained at 1961-1990 conditions.

		Diarrhea	**Inland Floods**	**Coastal Floods**	**Malaria**	**Dengue**
West Africa	**BaU**	1.08 (0.99 , 1.16)	1.66 (1 , 2.08)	1.64 (1.32 , 2.29)	1.02 (1.02 , 1.05)	1.28 (1 , 1.57)
Afr D	S750	1.06 (0.99 , 1.13)	1.99 (1 , 2.64)	1.48 (1.24 , 1.96)	1.01 (1.01 , 1.03)	1.2 (1 , 1.41)
	S550	1.05 (0.99 , 1.1)	2.3 (1 , 3.13)	1.44 (1.22 , 1.89)	1.01 (1.01 , 1.02)	1.19 (1 , 1.37)
South &East Africa	**BaU**	1.08 (0.99 , 1.16)	1.86 (1 , 2.44)	1.18 (1.09 , 1.35)	1.14 (1.14 , 1.28)	1.37 (1 , 1.75)
Afr E	S750	1.06 (0.99 , 1.13)	1.99 (1 , 2.65)	1.13 (1.07 , 1.27)	1.09 (1.09 , 1.18)	1.27 (1 , 1.54)
	S550	1.05 (0.99 , 1.11)	2.3 (1 , 3.18)	1.12 (1.06 , 1.25)	1.07 (1.07 , 1.15)	1.25 (1 , 1.49)
North America	**BaU**	1 (0.93 , 1.08)	7.99 (1 , 12.79)	1.19 (1.09 , 1.38)	1.51 (1.51 , 2.03)	1.46 (1 , 1.92)
Amr A	S750	1 (0.94 , 1.06)	9.66 (1 , 15.61)	1.14 (1.07 , 1.27)	1.33 (1.33 , 1.65)	1.33 (1 , 1.66)
	S550	1 (0.95 , 1.06)	11.5 (1 , 18.69)	1.13 (1.06 , 1.25)	1.27 (1.27 , 1.53)	1.3 (1 , 1.61)
Central, S America	**BaU**	1.02 (0.95 , 1.1)	2.4 (1 , 3.33)	4.64 (2.82 , 8.28)	1.08 (1.08 , 1.17)	1.3 (1 , 1.59)
Amr D	S750	1.02 (0.96 , 1.08)	2.26 (1 , 3.1)	3.76 (2.38 , 6.52)	1.05 (1.05 , 1.1)	1.22 (1 , 1.43)
	S550	1.02 (0.96 , 1.07)	2.92 (1 , 4.2)	3.58 (2.29 , 6.17)	1.04 (1.04 , 1.09)	1.2 (1 , 1.4)
South East Asia	**BaU**	1.09 (1 , 1.19)	1.21 (1 , 1.36)	1.04 (1.02 , 1.07)	1.01 (1.01 , 1.02)	1.17 (1 , 1.34)
	S750	1.07 (1 , 1.15)	1.39 (1 , 1.68)	1.03 (1.01 , 1.05)	1.01 (1.01 , 1.01)	1.12 (1 , 1.25)
	S550	1.06 (1 , 1.13)	1.73 (1 , 2.22)	1.03 (1.01 , 1.05)	1 (1 , 1.01)	1.11 (1 , 1.23)

5. Reference List

[1] D. Campbell-Lendrum, A. Pruss-Ustun, and C. Corvalan, How much disease could climate change cause? in: A. J. McMichael, D. Campbell-Lendrum, C. Corvalan, K. L. Ebi, A. K. Githeko, J. S. Scheraga, and A. Woodward (Eds.), Climate Change and Health: Risks and Responses, WHO, Geneva, 2003.

[2] A. J. McMichael, D. Campbell-Lendrum, R. S. Kovats, S. Edwards, P. Wilkinson, N. Edmonds, N. Nicholls, S. Hales, F. C. Tanser, D. Le Sueur, M. Schlesinger, and N. Andronova, Climate change, in: M. Ezzati, A. D. Lopez, A. Rodgers, and C. J. Murray (Eds.), *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors,* World Health Organization, Geneva, 2005.

[3] M. Ezzati, A. D. Lopez, A. Rodgers, S. Vander Hoorn, C. J. L. Murray, and Comparative Risk Assessment Collaborating Group, Selected major risk factors and global and regional burden of disease, Lancet, 360 (2002) 1347-1360.

[4] Climate change and health: Risks and Responses, WHO, Geneva 2003.

[5] C. J. Murray, Quantifying the burden of disease: the technical basis for disability-adjusted life years, Bull. World Health Organ., 72(3) (1994) 429-445.

[6] M. Hulme, J. Mitchell, W. J. Ingram, J. E. Lowe, T. C. Johns, M. New, and D. Viner, Global change scenarios for global impact studies, Global Environmental Change, 9 (1999) S3-S20.

[7] D. J. Rogers and S. E. Randolph, The global spread of malaria in a future, warmer world, Science, 289 (2000) 1763-1765.

[8] M. van Lieshout, R. S. Kovats, M. T. Livermore, and P. Martens, Climate change and malaria: analysis of the SRES climate and socio-economic scenarios, Global Environmental Change, 14 (2004) 87-99.