Short Literature Review on the Health Costs of Climate Change Adaptation

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List of Abbreviations

IPCC	Intergovernmental Panel on Climate Change
UVR	Solar Ultraviolet Radiation

1 Summary

This summary is an input to a larger piece of work by the Climate and Environment Division, in preparation of a cross-Whitehall International Climate Fund Board meeting in February 2011. Rather than being exhaustive, it intends to provide a brief overview of the available evidence to date.

2 Introduction – climate change and human health

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gases (GHG) concentrations. Continued GHG emissions at, or above, current rates would cause further warming and induce many changes in the global climate system during the 21st century, that would *very likely* be larger than those observed during the 20th century.

According to the 2007 report of Intergovernmental Panel on Climate Change (IPCC),[i] the projected climate trends are:

- Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights (virtually certain);
- Warm spells/heat waves. Frequency increases over most land areas (very likely);
- Heavy precipitation events. Frequency increases over most areas (very likely);
- Area affected by drought increases (likely);
- Intense tropical cyclone activity increases (likely);
- Increased incidence of extreme high sea level (excludes tsunamis) (likely).

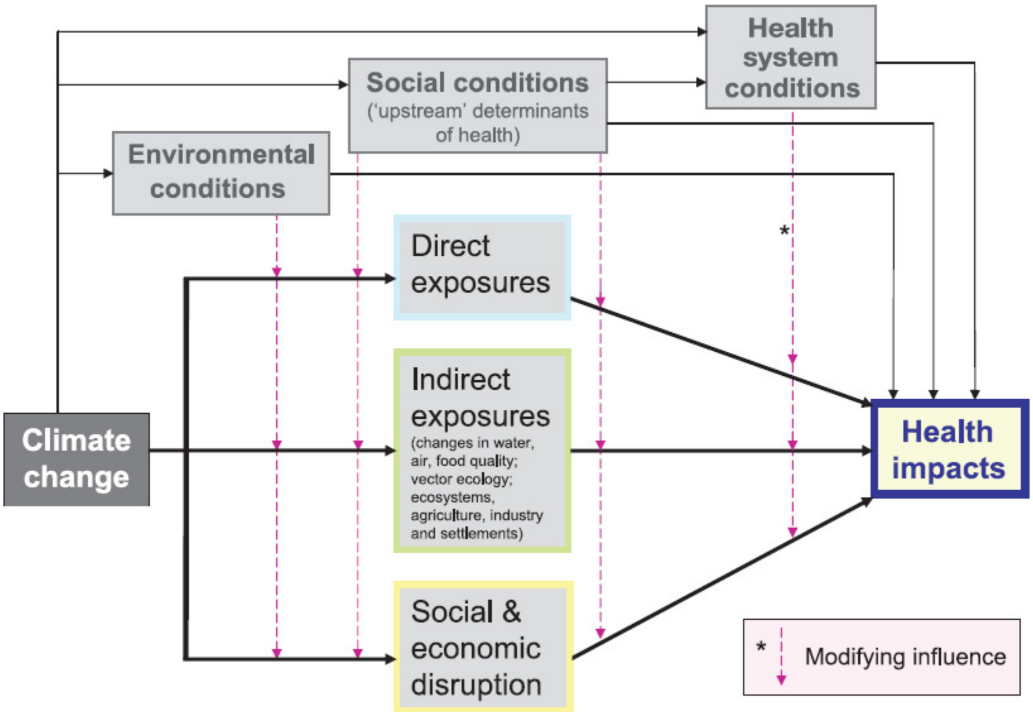
Climate change does not create a novel type of environmental exposure. Most of the health impacts of climate change arise as a result of the extension or amplification of existing health hazards. Human beings are exposed to climate change directly through changing weather patterns (e.g. heatwaves and extreme events such as floods) and indirectly though changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods, disease transmission and infrastructure.

Table 2 (p. 4) shows the projected impacts of climate change (on health, water, agriculture, forestry and ecosystems, society and settlements) in a simple framework. Section 2 of this paper outlines the **direct impacts** (respiratory and cardiovascular disease; flood related mortality and morbidity); section 3 outlines the **indirect impacts** (disease transmission; water related disease; food security and nutrition; and those linked to multiple stresses – population, migration, conflict).

A population's **vulnerability** is a joint function of, first, the extent to which a particular health outcome is sensitive to climate change and, second, the population's capacity to adapt to new climatic conditions. The vulnerability of a population depends on factors such as population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status and the quality and availability of public health care.[ii]

Figure 1 shows how climate change affects health outcomes, either directly or through multiple pathways determined by environmental, social and health-system factors.

Figure 1: Pathways of climate change impacts on human health



Source: IPCC 2007

All regions of the world are affected by a changing climate, but the resulting health risks to human populations vary greatly, depending on where and how people live. Those in the weakest economic position are often the most vulnerable to climate change and are frequently the most susceptible to climate-related damages, especially when they face multiple stresses. Thus, without mitigation and adaptation, climate change will increase health inequity especially through negative effects on the social determinants of health in the poorest communities.[iii] Existing ill health further increases vulnerability and reduces the capacity of individuals and groups to adapt. For example, in Africa and Asia the future course of the HIV/AIDS epidemic will significantly influence how well populations can cope with challenges such as the spread of climate-related infections, food shortages, and increased frequency of natural disasters.

The IPCC concludes with high confidence that adverse health impacts will be greatest in low-income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers, and coastal populations. Children have heightened risks, both because they suffer disproportionately from climate-sensitive disease and undernutrition and because they will be exposed longer to the accumulating damage that climate change is inflicting on the natural environment. There is also increasing evidence of greater vulnerability of specific groups such as the poor and elderly, not only in developing but also in developed countries.[iv]
Adaptive capacity, also connected to social and economic development, is unevenly distributed across and within societies. Empirical research has shown that

entitlements to elements of adaptive capacity are socially differentiated along the lines of age, ethnicity, class, religion and **gender**.[v]

Structural differences between men and women (e.g. gender-specific roles in society, work and domestic life) affect the vulnerability and capacity of women and men to adapt to climate change. In the developing world. in particular, women are disproportionately involved in natural resource-dependent activities, such as agriculture, which are affected by climate change. More women die than men from disasters. Statistics from past disasters including the Indian Ocean Tsunami and the 1991 Bangladesh Cyclone have showed women overrepresented in mortality rates.[vi] Women also endure a disproportionate amount of the burden during rehabilitation, as they are usually responsible for the additional care to children and the elderly. Table 1 summarises the gendered nature of risk and vulnerability for women.

Table 1: Gender aspects of vulnerability and adaptive capacity

Phenomena/Situation	Implications for women
Sudden impact natural hazards (floods, cyclones, mudslides etc)	• Greater risk of injury and death due to societal restrictions and gender roles. • Girls and women not encouraged to learn to swim in some cultures. • Women's clothing may limit mobility. • Inability to respond to warnings or leave the house without a male companion. • Loss of crops and livestock managed by women (with direct effect to family food security).
Slow onset hazards (drought, desertification, deforestation, land degradation)	• Increased workload to collect, store, protect, and distribute water for the household. • Increased domestic workload to secure food. • Increased numbers of women headed households due to men's migration. • Diminished access to collect food, fodder, wood, and medicinal plants.
Lesser access to early warnings and lower ability to respond	• Warnings in many cases do not reach women. • Lack of adequate awareness of how to act upon warnings. • Lack of life saving skills such as swimming and climbing. • Responsibility of carrying children and elderly to safety.
Lower ownership of land and other assets	• Less control over production and markets. • Less ability to adapt to ecological changes, resulting in crop failure. • Loss of income.
Lower income and access to resources	• Greater vulnerability in the face of shocks such as food shortages, crop failure, disasters. • Reduced ability to recover.

Adapted from: UNISDR, UNDP and IUCN (2009)

Phenomenon and trend	Likelihood*	Examples of major projected impacts	IPCC assessment of health impacts*
Warmer temperatures Fewer cold days and nights, warmer and more frequent hot days and nights Over most land areas)	Virtually certain (> 99% probability)	**Health**: Reduced mortality from decreased cold exposure in temperate climates. **Agriculture, forestry & ecosystems**: increased yields (cold environments); decreased yields (warmer environments); increased insect outbreaks. **Water:** effects on water resources relying on snowmelt; effects on some water supplies. **Society & settlements**: demand for heating reduced & increased for cooling; declining air quality in cities.	**High confidence** (about 8 out of 10 chance) • Alteration in seasonal distribution of some **allergenic pollen** species;
Warm spells/heat waves Frequency increases over most land areas	Very likely (> 90% probability)	**Health**: Increased risk of heat-related mortality, cardiovascular and respiratory disease. **Water**: increased demand; water quality problems (e.g. algae). **Agriculture, forestry & ecosystems**: reduced yields in warmer regions; increased danger of wildfires. **Society & settlements**: reduced quality of life for people in warm areas without appropriate housing, impacts on elderly, very young and poor.	**Very high confidence** (at least 9 out of 10 chance) • Mixed effects on **malaria**; in some places the geographical range will contract, elsewhere the geographical range will expand and the transmission season may be changed;
Heavy precipitation events frequency increases over most areas	Very likely (> 90% probability)	**Health**: increased risk of deaths, injuries, infectious, respiratory and other diseases **Agriculture, forestry & ecosystems**: damage to crops; soil erosion, waterlogging prevents cultivation. **Water**: effects on quality of surface and groundwater; contamination of water supply; possible relief to water scarcity. **Society & settlements**: Disruption due to flooding; pressures on urban and rural infrastructures; loss of property.	**High confidence** (about 8 out of 10 chance) • Increase in **cardio-respiratory** morbidity and mortality associated with ground-level ozone; • Continued alteration in distribution of some **infectious disease vectors**; • Increase in number of people suffering from death, disease and injury from **heatwaves, floods, storms, fires and drought**; • Some benefits to health, including fewer deaths from cold (but expected to be outweighed by the negative effects of rising temperatures, especially in developing countries;
Drought Areas affected increase	Likely (> 66% probability)	**Health**: increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases. **Water**: more widespread water stress. **Agriculture, forestry ecosystems**: land degradation; lower yields/crop damage and failure; increased risk of livestock deaths and wildfire.	

		Society & settlements: water shortages; reduced hydropower generation potentials; potential for population migration.	**Medium confidence** (about 5 out of 10 chance) • Increased burden of **diarrhoeal diseases**; • Increase in **heatwave**-related deaths; • Increase in **malnutrition** and consequences (e.g. child growth and development); **Low confidence** (about 2 out of 10 chance) • Increase in number of people at risk of **dengue**;
Intense tropical cyclones Activity increases	Likely (> 66% probability)	**Health**: increased risk of deaths, injuries, water and food-borne diseases. **Agriculture, forestry ecosystems**: damage to crops; uprooting of trees. **Water**: disruption to public water supply from power outages. **Society & settlements**: Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for migration; loss of property.	
Extreme high sea level (not tsunamis) Increased incidence	Likely (> 66% probability)	**Health:** Increased risk of deaths and injuries by drowning in floods; migration-related health effects. **Agriculture, forestry ecosystems**: salinisation of irrigation water, estuaries and freshwater systems. **Water:** decreased freshwater availability due to saltwater intrusion. **Society & settlements**: costs of coastal protection vs land use relocation; potential for movement of populations and infrastructure; see also tropical cyclone.	

Source: adapted from IPCC 2007, Synthesis Report.

* IPCC 07 assessment

3 Direct impacts

3.1 Climate trend: warmer temperatures; more extreme air temperatures (heat and cold); more air pollution.

- Increased deaths from respiratory and cardiovascular causes; heatstroke and heath stress;
- Heat and air pollutants increase cardiovascular and respiratory diseases.
- Some benefits from reduced cold related deaths in temperate climates, and from exposure to sun (vitamin D production).

Hot days, hot nights and heatwaves have already become more frequent.[vii] High temperatures raise the levels of ozone and other air pollutants, pollen and other aeroallergens.

Heat-related morbidity and mortality is projected to increase. Heatwaves are a direct contributor to deaths from cardiovascular and respiratory disease, particularly among elderly people. High temperatures also raise the levels of ozone and other air pollutants that exacerbate cardiovascular and respiratory disease, and pollen and other aeroallergens that trigger asthma.

Mortality from heatwaves depends on the severity of the heatwave and the health status of the population affected. Regions that are heavily urbanised will be more adversely affected than rural ones; in cities, high temperatures are exacerbated by the 'heat island' effect. Increasing numbers of older adults in the population also increase the proportion of the population at risk.

The excess deaths of the 2003 heatwave in Europe (estimated at 70,000) are likely to be linked to climate change.[viii] Lack of preparedness contributed to the excess deaths. A French parliamentary inquiry concluded that surveillance for heatwave deaths was inadequate, and the limited public-health response was due to a lack of experts, limited strength of public-health agencies, and poor exchange of information between public organisations.[ix]

Eighteen heatwaves were reported in India between 1980 and 1998, with a heatwave in 1988 affecting ten states and causing 1,300 deaths.[x] Heatwaves in Orissa, India, in 1998, 1999 and 2000 caused an estimated 2,000, 91 and 29 deaths respectively.[xi] Heatwaves in 2003 in Andhra Pradesh, caused more than 3000 deaths.[xii] However the mortality figures probably refer to reported deaths from heatstroke and are therefore an underestimate of the total impact of these events. Heatwaves in South Asia are also associated with high mortality in rural populations, and among the elderly and outdoor workers.[xiii]

Heat exposures vary widely, and current studies do not quantify the years of life lost due to high temperatures. Estimates of the burden of heat-related mortality attributable to climate change are reduced, but not eliminated, when assumptions about acclimatisation and adaptation are included in models. Overall, the health burden could be relatively small for moderate heatwaves in temperate countries, because deaths occur primarily in susceptible persons.[xiv] Additional research is needed to understand how the balance of heat-related and cold-related mortality could change under different socio-economic scenarios and climate projections.

The IPCC concludes (with high confidence) that warmer temperatures will bring some benefits to health, including fewer deaths from cold, although it is expected that these will be outweighed by the negative effects of rising temperatures worldwide, especially in developing countries. In the UK, reductions in cold-related deaths due to climate change are projected to be greater than increases in heat-related deaths.[xv]

Concentrations of air pollutants in general and fine particulate matter (PM) in particular, may change in response to climate change because their formation depends, in part, on temperature and humidity. Evidence for the health impacts of PM is stronger than that for ozone. PM is known to affect morbidity and mortality, so increasing concentrations would have significant negative health impacts.

In some regions, changes in temperature and precipitation are projected to increase the frequency and severity of fire events. Pollutants from forest fires can affect air quality for thousands of kilometres. Toxic gaseous and particulate air pollutants released into the atmosphere can significantly contribute to acute and chronic illnesses of the respiratory system, particularly in children, including pneumonia, upper respiratory diseases, asthma and chronic obstructive pulmonary diseases. For example, the 1997 Indonesia fires increased hospital admissions and mortality from cardiovascular and respiratory diseases in South-East Asia.[xvi]

Changes in wind patterns and increased desertification may increase the long-range transport of air pollutants (including aerosols, carbon monoxide, ozone, desert dust, mould spores and pesticides); under certain atmospheric conditions, this may occur over large distances and over time-scales typically of 4-6 days, which can lead to adverse health impacts. Windblown dust originating in desert regions of Africa, Mongolia, Central Asia and China can affect air quality and population health in remote areas. Dust can carry large concentrations of respirable particles, trace elements that can affect human health, fungal spores and bacteria. However, recent studies have not found statistically significant associations between Asian dust storms and hospital admissions in Canada and Taiwan.[xvii] Evidence suggests that local mortality, particularly from cardiovascular and respiratory diseases, is increased in the days following a dust storm.[xviii]

Climate change has caused an earlier onset of the spring pollen season in the Northern Hemisphere.[xix] Although there are suggestions that the abundance of a few species of air-borne pollens has increased due to climate change, and it is reasonable to conclude that allergenic diseases caused by pollen have experienced changes in seasonality,[xx] it is unclear whether the allergenic content of these pollen types has changed, and there is limited evidence that the length of the pollen season has also increased for some species.

Hot temperatures also have implications for occupational health and safety. Risks of working in hot environments include a diminished ability to carry out physical tasks, diminished mental task ability, and accidents; if prolonged, may lead to heat exhaustion or heatstroke. Both outdoor and indoor workers are at risk of heatstroke. Acclimatisation in tropical environments does not eliminate the risk, as shown by the occurrence of heatstroke in metal workers in Bangladesh and rickshaw pullers in South Asia.[xxi]

Solar ultraviolet radiation (UVR) exposure causes a range of health impacts. The balance of effects is difficult to predict and will vary depending on location and present exposure to UVR. The greatest burdens result from UVR-induced cortical cataracts, cutaneous malignant melanoma, and sunburn (though data on the latter is scarce). UVR exposure may weaken the immune response to certain vaccinations, which would reduce their effectiveness. There are also important health benefits: exposure to radiation in the ultraviolet B frequency band is required for the production of vitamin D in the body. Lack of sun exposure may lead to osteomalacia (rickets) and other disorders caused by vitamin D deficiency.

Cold-waves are a problem in northern latitudes. Accidental cold exposure occurs mainly outdoors, among socially deprived people (e.g. the homeless), workers, and the elderly in temperate and cold climates. Even where populations are well adapted to cold conditions, if electricity or heating systems fail cold-waves can still cause substantial increases in mortality. Cold-waves also affect health in warmer climates, such as in South-East Asia.

3.2 Climate trend: increase in frequency of heavy precipitation events

- Increased morbidity and mortality from floods and storms: deaths, injuries, infectious diseases and toxic contamination, mental health problems.

Impervious surfaces, along with inadequate drainage and precarious housing, increase the risks and the health impacts of flash floods. Although improved measures, particularly improved warnings, have decreased mortality from floods and storm surges in the last 30 years, the impact of weather disasters in terms of social and health effects is still considerable, and is unequally distributed. In terms of deaths and populations affected, floods and tropical cyclones have the greatest impact in South Asia and Latin America. Poorer communities, particularly slum dwellers, are more likely to live in flood-prone areas. High-density populations in low-lying coastal regions experience a high health burden from weather disasters.

Flood health impacts range from deaths, injuries, infectious diseases and toxic contamination, to mental health problems. Deaths recorded in disaster databases are from drowning and severe injuries. Deaths from unsafe or unhealthy conditions following the extreme event are also a health consequence, but such information is rarely included in disaster statistics.

The risk of infectious disease following flooding is generally low in high income countries. Populations with poor sanitation infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events, increases in cholera, cryptosporidiosis, and typhoid fever.[xxii] In 1998, increased rainfall and flooding after hurricane Mitch in Nicaragua, Honduras, and Guatemala caused a leptospirosis outbreak, and an increased number of cases of malaria, dengue fever, and cholera.[xxiii] In 1993 floods in Wisconsin promoted outbreaks of cryptosporidiosis (400,000 cases and 100 deaths).[xxiv]

Flood related increases in diarrhoeal disease have also been reported in India, Brazil, Bangladesh and Mozambique in 2001 (with an estimated 8,000 additional cases and 447 deaths from diarrhoeal disease in the month following the floods).[xxv]

Flooding may also lead to contamination of waters with dangerous chemicals, heavy metals or other hazardous substances (e.g. pesticides). Chemical contamination following Hurricane Katrina included oil spills from refineries and storage tanks, pesticides, metals and hazardous waste. Increases in population density and accelerating industrial development in areas subject to natural disasters increase the probability of future disasters and the potential for mass human exposure to hazardous materials released during disasters. However, there is little published evidence demonstrating a causal effect of chemical contamination on the pattern of morbidity and mortality following flooding events.

There is increasing evidence of the importance of mental disorders as an impact of disasters. Prolonged impairment resulting from common mental disorders (anxiety and depression) may be considerable. However the mental health aspect of flood-related impact has not been widely researched.

Glacier lake outburst floods, a unique risk to mountain regions, are projected to increase, as the rate of glacier melting increases. These are also associated with high morbidity and mortality.

4 Indirect impacts

4.1 Changing patterns of infection

4.1.1 Climate trend: rising temperatures

- Warmer temperatures change patterns of infection;
- Increased risk for populations with little or no immunity to new infections;
- Transmission zones of malaria increase or change;
- Transmission zone of dengue fever widens;
- Increases or changes in distribution of other infections: e.g. schistosomiasis, Lyme disease, tick-borne encephalitis.

Infections caused by pathogens that are transmitted by insect, rodent vectors, snails and other cold-blooded animals are sensitive to climate. Extreme events (rains or drought) also affect distribution and spread of disease.

Temperature affects rate of pathogen maturation and replication within mosquitoes, the density of insects in a particular area, and increases the likelihood of infection. Therefore, some populations who have little or no immunity to new infections might be at increased risk. Effects can be amplified where health services may not have experience in controlling or treating previously unseen infections.

Vector reproduction, parasite development cycle, and bite frequency generally rise with temperature, making malaria, tick-borne encephalitis, and dengue fever increasingly widespread.

4.1.1.1 Malaria

The IPCC has ‘very high confidence’ of the mixed effects on malaria: in some places the geographical range will contract, elsewhere the geographical range will expand and the transmission season may be changed.[xxvi]

The causal links between climate and malaria transmission dynamics are known, but there is still much uncertainty about the potential impact of climate change on malaria at local and global scales. All published models have limited parameterisation of some of the key factors that influence the geographical range and intensity of malaria transmission.[xxvii]

Lindsay and Martens have used mathematical models and scenarios to estimate that 260-320m more people will be affected by malaria by 2080 as a consequence of new transmission zones (warm high altitudes once free of malaria).[xxviii] Other modelling studies provide similar estimates.[xxix] A modelling study of population dynamics of mosquitoes in relation to warming in east African highlands sites found that mosquito abundance is amplified with warming, with an over ten-fold increase with every unit increase (0·1℃) in temperature.[xxx] In Kenya, meteorological factors were associated with malaria incidence, with temperature having the largest effect.[xxxi] This finding suggests that temperature rises will increase malaria cases. However others have cautioned against attributing malaria dynamics to climate change and point to the uncertainties of predicting malaria epidemics nationally and locally.[xxxii]

Projections also suggest that some regions will experience a longer season of transmission; this may be as important as geographical expansion for the attributable disease burden. Although an increase in months per year of transmission does not directly translate into an increase in malaria burden[xxxiii], it would have important implications for vector control.

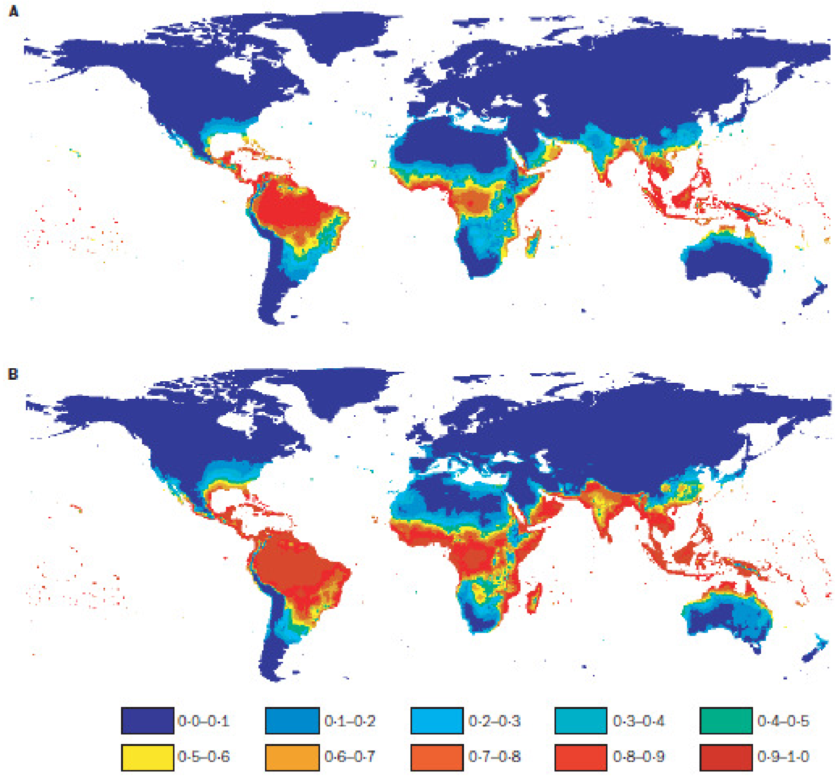
Rainfall is an important limiting factor in disease transmission. Malaria has decreased in association with long-term decreases in annual rainfall in Senegal and Niger.[xxxiv]

4.1.1.2 Dengue fever.

Approximately one-third of the world’s population lives in regions where the climate is suitable for dengue transmission.[xxxv] Cases have risen dramatically in the last 40 years, as unplanned urbanization with standing water in waste and other receptacles have created mosquito breeding sites, and movement of people and goods has spread both mosquito vectors and infections. Heavy rainfall and a rise in temperature increase the rate of infection.[xxxvi]

Hopp and Foley found strong correlations between climate-induced variations in modelled mosquito populations and reported historical dengue/dengue haemorrhagic fever cases, especially in some Central American and Southeast Asian countries.[xxxvii] A logistic regression empirical model with vapour pressure (humidity) as a predictor of dengue fever risk, suggests that, in the absence of changes in other determinants, climate change could expose an additional two billion people to dengue by 2085s through increases in the areas with a climate suitable for transmission, including Australia and New Zealand.[xxxviii]

Figure 2: A: Estimated baseline population at risk of dengue fever in 1990
B: estimated population at risk in 2085



4.1.1.3 Other Diseases

Modelling studies project that diseases such as schistosomiasis, fascioliasis, alveolar echinococcosis, leishmaniasis, Lyme borreliosis, tick-borne encephalitis, and hantavirus infections will increase as a result of global climate change.[xxxix] For example, a biology-driven model estimates a significant expansion of the area of China where schistosomiasis transmission occurs.[xl] However some research attributes changes in disease patterns, such as for tick-borne encephalitis, to socioeconomic rather than climate change.[xli]

There is no clear evidence at present for a climate effect on influenza or avian flu.[xlii]

Ecosystem modifications (both through climate change and other causes) could also lead to disease outbreaks, or alter the proportions of competent and incompetent hosts. Competent reservoir hosts tend to thrive in species-poor communities, therefore vectors are more likely to feed upon these competent reservoirs and become infected, and the risk of human disease is increased. This effect might occur in Lyme, West Nile, and hantavirus diseases.[xliii]

4.1.2 Climate trend: drought

- Increased risks of mosquito-borne disease outbreaks.
- Effect on meningococcal meningitis outbreaks (but causality not clear).

The transmission of some mosquito-borne diseases is affected by drought events. During droughts, mosquito activity is reduced and, as a consequence, the population of non immune persons increases. When the drought breaks, there is a much larger proportion of susceptible hosts to become infected, thus potentially increasing transmission. In other areas, droughts may favour increases in mosquito populations due to reductions in mosquito predators. Other drought related factors that may result in a short-term increase in the risk for infectious disease outbreaks include stagnation and contamination of drainage canals and small rivers.

The geographical distribution of meningococcal (epidemic) meningitis has expanded in West Africa in recent years, which may be attributable to environmental change driven by both changes in land use and regional climate change.[xliv] Meningococcal meningitis is endemic in West African countries within the Sahelo-Sudanian band (the 'meningitis belt); the spatial distribution, intensity and seasonality of meningococcal meningitis appear to be strongly linked to climatic and environmental factors, particularly drought, although the causal mechanism is not clearly understood.

Drought events are also associated with dust storms and respiratory health effects; and with water scarcity and risks of water-washed diseases (caused by lack of hygiene).

4.2 Water

4.2.1 Climate trend: more frequent heavy precipitation - water and disease

- Exacerbation of health hazards caused by lack of safe water.
- Where water and sanitation services are inadequate, higher temperatures may facilitate transmission of diarrhoea.
- Outbreak of diseases due to extreme events, where the public water supply is weak.

Climate-change-related alterations in rainfall, surface water availability and water quality affect the burden of water-related diseases, either water-borne (ingested) or water-washed (caused by lack of hygiene)

Average annual rainfall is forecast to decrease in some regions and increase in others, and droughts and floods are likely to become more frequent and intense. Regional patterns of rainfall might also be altered: the problem is not simply sustained drought, but also severe rainfall all at once followed by less rainfall (thus annual rainfall might rise, but still cause drought).

There are several ways in which climatic alterations related to water can affect health outcomes:

- Linkages between water availability, household access to improved water, and the health burden due to diarrhoeal diseases.

It is unclear what proportion of the current burden of malnutrition, infant mortality and diseases related to contaminated or insufficient water can be attributed to climate variability or extremes. Attribution to climate change is difficult. However, given that provision of public health infrastructure and access to safe water remain a challenge in many parts of the world, reductions in the availability and reliability of freshwater supplies are expected to amplify this hazard.

- Direct effects of temperature on the incidence of diarrhoeal and other disease.

Higher temperatures and too much or too little water can all facilitate transmission. In countries with inadequate water and sanitation services, diarrhoea is much more common when temperatures are high. The strongest evidence comes from rates of diarrhoeal disease in Lima, Peru, which are 3-4 times higher in the summer than in the winter, increasing by 8% for every 1°C increase in temperature.[xlv] Associations between monthly temperature and diarrhoeal episodes have also been reported in the Pacific islands, Australia and Israel.[xlvi]

- The role of extreme rainfall (intense rainfall or drought) in facilitating water-borne outbreaks of diseases through piped water supplies or surface water.

Reductions in rainfall lead to low river flows, reducing effluent dilution and leading to increased pathogen loading. This could represent an increased challenge to water-treatment plants. During the dry summer of 2003 low river flow in the Netherlands resulted in changes in water quality.[xlvii]

Extreme rainfall and runoff events may increase microbial load in watercourses and drinking-water reservoirs; however the linkage to cases of human disease is less certain. The seasonal contamination of surface water in early spring in North America and Europe may explain some of the seasonality in sporadic cases of water-borne diseases such as cryptosporidiosis and campylobacteriosis.[xlviii] The marked seasonality of cholera outbreaks in the Amazon is associated with low river flow in the dry season, probably due to pathogen concentrations in pools.[xlix] Well managed public water supply systems should be able to cope with climate extremes.

Cholera transmission is primarily associated with poor sanitation. However as ocean temperatures rise with global warming and more intense El Niños, cholera outbreaks might increase as a result of more plankton blooms providing nutrients for Vibrio cholerae.[l]

There is little information on the possible health consequences of climate change in mountain regions, where vector-borne pathogens could take advantage of new habitats at altitudes that were formerly unsuitable, and diarrhoeal diseases could become more prevalent with changes in freshwater quality and availability.

- Effects of temperature and runoff on microbiological and chemical contamination of coastal, recreational and surface waters.

Climate change is also likely to affect the quality of coastal waters, by changing natural ecosystems or the quality of the waters draining into the coastal zone. This poses specific risks for the recreational use of bathing waters, particularly for transient tourist populations that may not have built-in resistance to endemic water-related diseases or may be faced with water quality that does not meet the stringent conditions imposed in the home country. The quality and safety of seafood is also directly linked to the quality of the water in the coastal zone.

4.2.2 Water stress

The IPCC concludes that there will be decreasing water availability and increasing drought in middle latitudes and semi-arid low latitudes (e.g., the Mediterranean Basin, western USA, southern Africa and northeastern Brazil); that groundwater recharge will decrease considerably in some already water-stressed regions (high confidence), where vulnerability is often exacerbated by the rapid increase in population and water demand.

In some regions such as South East Asia increased rainfall could reduce absolute water scarcity. However, the health benefits will depend on the capacity to store additional runoff, which is predicted to occur during the wettest rather than driest seasons.

Increasing rates of glacial melting are predicted to lead to great reductions in river flow and freshwater availability. Earlier snow thawing due to rising temperatures and increased rain relative to snow precipitation, can potentially exacerbate dry season water scarcity. These changes can have significant impacts on the communities from mountains to plains that rely on freshwater runoff. For example, in China, 23% of the population live in the western regions where glacial melt provides the principal dry season water source.

Reduced river flows and increased water temperature will lead to declining water quality as the dilution of contaminants is reduced, less oxygen is dissolved in water, and microbiological activity increases. These effects could lead to major health problems for vulnerable people, especially during drought, and might increase the risk of conflict and major population migration.

Water stress also necessitates the use of new water sources, including recycled wastewater for agriculture. Unless properly managed, the use of recycled wastewater can facilitate exposure to microbial contaminants and chemicals, including pesticides and fertilizers. Decreasing and more erratic water supplies are expected to add to the burden of diarrhoeal disease.

In many regions, these effects will come on top of pre-existing water stress and mounting pressures of population growth, as well as extraction for irrigation and contamination from agriculture and industry.

4.3 Food security and nutrition

4.3.1 Climate trend: warmer temperatures; droughts; rising sea levels.

- Negative effect on crops (but also forestry, livestock, fisheries, aquaculture, and water system) leading to food shortages;
- Hunger, illness, and death due to undernutrition worsen;
- Malnutrition may be one of the most important consequences of climate change due to the very large number of people that may be affected.

4.3.1.1 Food Security

Prediction on how climate change will affect agricultural production is lacking. However expert assessments of future food security are generally pessimistic over the medium term.

Several studies suggest that rising temperatures will affect crops. One statistical model has shown that corn and soyabean yields in the USA fell by 17% for every degree rise in growing season temperature.[li] Previous studies predicted changes of similar magnitude for a 3°C temperature increase.[lii] Lobell et al used statistical crop models and climate projections for 2030 from 20 general circulation models, showing that south Asia and southern Africa, without sufficient adaptation measures, are likely to suffer negative outcomes on food crops such as maize, wheat, and rice.[liii] Projections by Battisti and Naylor suggest that harvests of staple food crops, such as rice and maize, could fall between 20% and 40% as a result of increased temperatures during the growing season in tropical and subtropical regions (home to about half the world's population).[liv]

Agricultural productivity might also increase in some regions as a result of global warming; however this will be entirely in the rich high-latitude countries, although Sahara greening might benefit west Africa.[lv]

Hunger, illness, and death due to undernutrition can worsen as climate change affects not only crops but also forestry, livestock, fisheries, aquaculture, and water systems. Increases in extreme weather events will damage crops and disrupt farming. Sea level rise and flooding of coastal lands will lead to salination or contamination of fresh water and agricultural lands, and the loss of nursery areas for fishing. Drought, and changing patterns of plant and livestock diseases and pest infestations, reduction of income from animal production, decreased crop yields, lessened forest productivity, and changes in aquatic populations will all affect food production and security.

The regions most likely to be adversely affected are those already most vulnerable to food insecurity and malnutrition, where production is undertaken by smallholder and subsistence farmers, pastoralists, traditional societies, indigenous people, coastal populations, and artisanal fisherfolk. There is particular concern for sub-Saharan Africa, where people are most reliant on subsistence and rain-fed agriculture and have least money to buy imported food.

4.3.1.2 Nutrition

Both acute and chronic nutritional problems are associated with climate variability and change. The linkages are complex (the causal chains may involve regional water scarcity, salinisation of agricultural lands, destruction of crops through flood events, disruption of food logistics through disasters, and increased burden of plant infectious diseases or pests). This makes attribution of current and future climate-change-related malnutrition burdens problematic.

However, due to the very large number of people that may be affected, malnutrition linked to extreme climatic events may be one of the most important consequences of climate change. For example, climate change is projected to increase the percentage of the Malian population at risk of hunger from 34% to between 64% and 72% by the 2050s, although this could be substantially reduced by the effective implementation of a range of adaptive strategies.[lvi]

Climate-change models project that those likely to be adversely affected are the regions already most vulnerable to food insecurity, notably Africa, which may lose substantial agricultural land. Overall, climate change is projected to increase the number of people at risk of hunger.[lvii]

The areas affected by drought are projected to increase.[lviii] The effects of drought on health include deaths, malnutrition (undernutrition, protein-energy malnutrition and/or micronutrient deficiencies), infectious diseases and respiratory diseases.

Drought diminishes dietary diversity and reduces overall food consumption, and may therefore lead to micronutrient deficiencies. In Gujarat, India, during a drought in the year 2000, diets were found to be deficient in energy and several vitamins.[lix] An epidemiological study in southern Africa suggests that HIV and AIDS amplify the effect of drought on nutrition.

Malnutrition increases the risk both of acquiring and of dying from an infectious disease. A study in Bangladesh found that drought and lack of food were associated with an increased risk of mortality from a diarrhoeal illness.[lx]

Drought and the consequent loss of livelihoods is also a major trigger for population movements, particularly rural to urban migration. Population displacement can lead to increases in communicable diseases and poor nutritional status resulting from overcrowding, and a lack of safe water, food and shelter. Recently, rural to urban migration has been implicated as a driver of HIV transmission.[lxi]

4.3.1.3 Food Safety

Rising temperatures also have implications for food safety. They are linked to common forms of food poisoning, such as salmonellosis, with studies finding an approximately linear increase in reported cases with each degree increase in weekly or monthly temperature.

Contact between food and pest species, especially flies, rodents and cockroaches, is also temperature-sensitive. In temperate countries, warmer weather and milder winters are likely to increase the abundance of flies and other pest species during the summer months, with the pests appearing earlier in spring.

Harmful algal blooms produce toxins that can cause human diseases, mainly via consumption of contaminated shellfish. Also other pathogens responsible for non-viral infections related to shellfish consumption depend on the salinity and temperature of the coastal water. Warmer seas may thus contribute to increased cases of shellfish poisoning.

4.4 Effects of multiple stresses

WHO points out that in the long run, the greatest health risks may be not from natural disasters or disease epidemics, but from the slow build-up of pressures on natural, economic and social systems that sustain health.[lxii] These are already under stress, particularly in the developing world.

4.4.1 Population pressure

Population growth is expected to interface with climate change in ways that intensify several other mechanisms, especially shelter, food, and water scarcity. It will increase pressure and competition for scarce resources, such as food, water, and land. To compensate, production will rise, resulting in even greater environmental degradation of arable land.

Population growth is expected to be absorbed mostly by the less developed regions, while the population of developed regions is expected to remain mainly unchanged. Population growth also puts additional stress on already weak health systems and exacerbates vulnerability to the adverse health effects of climate change.

Demographic change is also a key driver of greenhouse gas emissions. Despite uncertainty over the exact point at which global population size becomes a defining driving force of climate change, there is general agreement that there is a strong positive relationship between population growth and climate change that will become more pronounced as this century progresses.

4.4.2 Migration

The association between climate change and migration is complex, and it can be difficult to isolate environmental factors from other drivers of migration - political, social, and economic. A distinction is usually made between slow-onset processes and extreme environmental events or natural disasters – distinguishing, for example, desertification from floods. While natural disasters tend to generate temporary movements, slow-onset processes may lead to long-term or permanent migration.[lxiii] By destroying ecological and agricultural systems and by flooding communities, climate change can eventually force people to abandon flooded, arid and inhospitable environments. Forced displacement is associated with a range of health issues, including social isolation and mental disorders and, in many cases, reduced socioeconomic status and associated health problems. The recent drought in Australia caused many rural families to abandon their farms and move to cities, with a range of negative social and health effects.[lxiv]

There is little evidence that large scale migration, with hundreds of millions of environmental refugees, may become a reality.[lxv] Past experiences suggest that short-distance and short-term movements will probably increase, with the very poor and vulnerable in many cases unable to move.[lxvi] However migrant groups are more vulnerable to a range of stressors including poor access to health care.

When migration crosses ethnic and/or national boundaries (e.g. forced migration from low-lying, small island states) the social transition is more difficult and the associated health effects are likely to be more severe. However the effect of rising sea levels on migration is uncertain. First, sea level rise does not only depend on the rate of global temperature rise but also on the rate of natural processes such as subsidence. Second, little can be inferred from past experience. The number of people forced to move will also depend on adaptation initiatives and wider national planning strategies.

4.4.3 Conflict

Similar to migration, the association between climate change and conflict is difficult to quantify. Climate change can be one contributing factor. Stresses on natural ecosystem services, with competition over dwindling or degraded natural resources, can lead to tensions between population groups over, for example, freshwater supplies or fertile agricultural land. Combined with factors such as poor governance and ethnic rivalries, such competition can inflame tensions into conflict.

The association between climate change and conflict has been observed in Darfur. Average rainfall in southern Sudan dramatically fell in recent decades, coinciding with warming of the Indian ocean. The UN Environment Programme recognises that climate change and desertification have been an additional stressor to the population, influencing migration to the south; thus it might have contributed to initiation of the conflict.[lxvii]

5 Key issues/hotspots (in regions of interest to DFID)

This section is summarised from IPCC 2007 (Chapters 8, 9 and 10).

Asia

- Uncertainties: large natural climate variability in Asia; currently relatively low understanding of the precise magnitude of climate change due to anthropogenic factors.
- Human health: High Confidence that human health will be affected in East and South-East Asia subregions; Medium confidence for North, Central and South Asia (IPCC07).

Table 2: Key issues in Asia

Issue	Where	Confidence (IPCC 2007)
Diarrhoea Increases in endemic morbidity and mortality	South and South-East Asia	High
Cholera Warmer sea-surface temperature exacerbating abundance and/or toxicity; contamination of drinking water	South Asia	High
Vector-borne & water-borne diseases Natural habitats likely to expand *(Malaria, schistosomiasis, dengue fever; cholera)*	North Asia	Medium
Heat stress Increased frequency and occurrence	Central, East, South and South-East Asia	n/a
Cardiovascular & respiratory illnesses Urban air quality deteriorating in newly industrialised areas	e.g China and Indonesia	n/a
Water Reduced freshwater availability	Central, South, East and South-East Asia	n/a
Agriculture Significant regional variations. Likely northward shift of agricultural zones. Increased need for irrigation in South and East Asia		n/a
Food security / nutrition There are uncertainties but serious concerns about the prevalence of malnutrition among poorest/marginalised, esp. rural children. Increasing urbanisation and population likely to increase demand and reduce supply due to limited availability. Exacerbated by loss of cultivated land and nursery areas for fisheries in low-lying tropical areas.	Regional variations & significant uncertainties.	n/a
Sea level rise Significant losses of coastal ecosystems; 1m people along the coasts likely at risk from flooding. Effects on infrastructure esp. in heavily-populated megadeltas.	South and South-East Asia	High
Multiple stresses Pressures on natural resources and the environment associated with rapid **urbanisation**, industrialisation, and economic development.		High

n/a: confidence level not assigned

Africa

- Uncertainties: significant knowledge gaps in various areas. Regional and local-level climate models and scenarios are lacking.
- Human health: high confidence that human health, already compromised by range of factors, could be further negatively impacted by climate change and climate variability.

Table 3: Key issues in Africa

Issue	Where	Confidence (IPCC 2007)
Malaria Previously malaria-free highland areas could become suitable for transmission; areas currently with low rates of malaria transmission could also become highly suitable. Possible contraction of areas suitable for transmission western Sahel and much of southern central Africa.	Southern Africa and the East African highlands. Southward expansion of the transmission zone into South Africa may occur.	n/a
Other diseases Possible increased prevalence of some vector-borne diseases (e.g., malaria, dengue fever), and vulnerability to water, food or person-to-person diseases (e.g. cholera, dysentery) Possible interaction with other background stresses and additional vulnerabilities such as HIV, conflict and war.		n/a
Agricultural production and food security Agricultural production and food security (including access to food) in many African countries and regions likely to be severely compromised by climate change and climate variability. A number of countries already face semi-arid conditions; climate change is likely to reduce the length of growing season and force large regions of marginal agriculture out of production. Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected. This would adversely affect food security in the continent. Declining quantity and quality of drinking water can worsen malnutrition. Agriculture and the growing seasons in certain areas may lengthen (e.g. parts of Ethiopian highlands and southern Africa such as Mozambique).	Sahara, West and Central Africa, Southern Africa	High
Water Aggravation of water stress currently faced by some countries, other countries will become at risk of water stress. Even without climate change, several countries (esp. in northern Africa) will exceed the limits of their economically usable land-based water resources before 2025. About 25% of Africa's population (about 200m people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 75-250m and 350-600m people by the 2020s and 2050s, respectively.	Possible heightened water stress in some Southern Africa river basins	Very high
Ecosystems Changes are already being detected (esp. Southern Africa desertification) at a faster rate than anticipated. Threat to forest (also through human interaction); By the 2080s, the proportion of arid and semi-arid lands is likely to increase by 5-8%.		Very high

Sea level rises Increases in socio-economical and physical vulnerability of cities. Could increase flooding, particularly on the coasts of eastern Africa with implications for health.		High
Multiple stresses One of the most vulnerable continents to climate change and climate variability, situation aggravated by the interaction of multiple stresses, occurring at various levels, and low adaptive capacity.		High

n/a: confidence level not assigned

6 Adaptation strategies

Table 4 shows possible adaptation options for various sectors that have an impact on health. It is not exhaustive as the focus of this brief paper is on the health sector.

Table 4: Selected examples of adaptation strategies

Sector	Adaptation option/strategy	Policies	Constraints and *opportunities*
Water	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency. Construction, maintenance, and operation of water and sanitation systems that are affordable, and resilient to flood and drought, while avoiding high water consumption. Co-management of water for agriculture and Ecosystems.	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *Integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; crop relocation; improved land management, irrigation management, water harvesting and conservation technologies, diversification of agriculture systems; development of drought resistant crops Addressing patterns of food consumption. Co-management of water for agriculture and ecosystems. Changes in management of emergencies (i.e. cash donations to purchase food from regional or local markets instead of food aid). Rural development to reduce urban drift and rural degradation.	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *Longer growing season in higher latitudes; revenues from 'new' products*

Infrastructure /settlement	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers. Rural development to reduce degradation & urbanisation drift. Infrastructure and services to reduce hazard and vulnerability. Design of houses and settlements against thermal extremes.	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human health	Improved climate-sensitive disease surveillance and control; early warning systems and empowering communities to achieve effective disease surveillance; emergency medical services; (see also Section 6)	Public health policies that recognise climate risk; Strengthened health services; Regional and international cooperation.	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *Upgraded health services; improved quality of life*
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage.	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *Improved technologies and integration with key sectors; roads facilitate access to health services.*

Adapted from: IPCC 2007 (Synthesis Report); Costello 2009.

7 Costs

7.1 Disease burden ('damage costs')

Most of the health impacts of climate change arise as a result of the extension or amplification of existing health hazards. Despite some potential benefits, the negative effects are concentrated on poor populations that already have compromised health prospects, and weak health systems.

A modelling study by Campbell-Lendrum et al (WHO 2003) is the first global approximation of the likely scale of climate change effects on a range of impacts, based on data from 2000 (Table 5). Health outcomes were chosen on the basis of sensitivity to climate variation, predicted future importance by IPCC and availability of quantitative global models, or feasibility of constructing them. Limited adjustments for adaptation were included in the estimates.

Key conclusions from the study include:

- Proportional changes in impacts such as diarrhoea and malnutrition are quite modest (compared to floods for example) but are likely to be extremely important in public health because they relate to such a **large burden** of disease.
- The impacts are likely to be much larger in the **poorest regions of the world**.
- **Diarrhoea**: in 2030 the risk of diarrhoea will be up to 10% higher in some regions than if no climate change occurred.
- **Malnutrition**: estimated effects vary markedly across regions; from a significant increase in the south-east Asia region, to a small decrease in the western Pacific region.
- **Floods**: proportional changes in the numbers of people killed in *coastal* floods are very large, but induce a low disease burden in terms of people immediately killed and injured. Impacts of *inland* floods are predicted to increase by a similar order of magnitude and generally cause a greater acute disease burden. The relative increase in risks tends to be similar in developed and developing regions. However, these apply to baseline rates that are much higher in developing than developed countries. Uncertainty around the likely effectiveness of adaptation measures, and the quantitative relationships between changes in precipitation, the frequency of flooding and associated health impacts

Malaria: relatively large changes in relative risk in regions bordering current endemic zones. Relative changes are smaller in areas that already are highly endemic, mainly because increases in transmission in already endemic zones are was not considered in the analysis

Table 5: Estimates for the impact of climate change in 2000 in thousands of DALYs*

	Malnutrition	Diarrhoea	Malaria	Floods	Total	Total DALYs/ million population
African region	616	414	860	4	**1894**	**3071.5**
Eastern Mediterranean region	313	291	112	52	**768**	**1586.5**
Latin American and Caribbean region	0	17	3	72	**92**	**188.5**
South-East Asian region	1918	640	0	14	**2572**	**1703.5**
Western Pacific region[a]	0	89	43	37	**169**	**111.4**
Developed countries[b]	0	0	0	8	**8**	**8.9**
World	2847	1460	1018	192	**5517**	**920.3**

[a] without developed countries.
[b] and Cuba.

* given by applying the relative risk estimates for 2000 to the DALY burdens for specific diseases quoted in the World Health Report (2002)

Source: How much disease could climate change cause? D.H. Campbell-Lendrum, C.F. Corvalán, A. Prüss–Ustün. In: *Climate change and human health: risks and responses*. A. J. McMichael et al, eds. WHO 2003.

Similar conclusion are drawn in WHO 2004 study with updated GBD (Table 6)

Table 6: Estimated disease burden (000s of DALYs) attributable to climate change in the year 2000, by cause and subregion

Subregion	*Malnutrition*	*Diarrhoea*	*Malaria*	*Floods*	*All causes*	*Total DALYs/million population*
AFR-D	293	154	178	1	626	2 185.78
AFR-E	323	260	682	3	1 267	3 839.58
AMR-A	0	0	0	4	4	11.85
AMR-B	0	0	3	67	71	166.62
AMR-D	0	17	0	5	23	324.15
EMR-B	0	14	0	6	20	147.57
EMR-D	313	277	112	46	748	2 145.91
EUR-A	0	0	0	3	3	6.66
EUR-B	0	6	0	4	10	48.13
EUR-C	0	3	0	1	4	14.93
SEAR-B	0	28	0	6	34	117.19
SEAR-D	1 918	612	0	8	2 538	2 080.84
WPR-A	0	0	0	1	1	8.69
WPR-B	0	89	43	37	169	111.36
World	2 846	1 459	1 018	193	5 517	925.35

Source: McMichael, AJ et al (2004) Global Climate Change. In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*, ed. M. Ezzati, A. Lopez, A. Rodgers, and C. Murray, 1543–649. Geneva: WHO

7.2 Health adaptation costs

The magnitudes of costs of adaptation in the health sector are unknown but potentially large. Not implementing additional adaptation will be even more expensive in terms of the burden of additional injuries, illnesses and deaths on society. The current lack of investment in public health is a considerable barrier to adaptation. However, investment alone is not sufficient to improve health in developing countries, as many other barriers remain, such as poor governance, inequality and low adaptive capacity (IIED 2009).

Health 'adaptation costs' include:

- Costs of improving or modifying health protection systems e.g. expanding health or vector surveillance systems – this includes the costs associated with building new infrastructure, increasing laboratory and other capacities, and training new health care workers; disaster preparedness including training and keeping a roster of emergency health professionals; community-based first aid training, e.g. to deal both with new risks (e.g. heat strokes) or post- disaster health needs;
- Costs of introducing novel health interventions (e.g. heat-wave or other broader early warning systems);
- Additional costs for meeting environmental and health regulatory standards (e.g. air quality standards, water quality standards);

- Costs of improving or modifying health systems infrastructure, e.g. adapting hospitals to hotter summers; 'disaster proofing' existing and new infrastructure;
- Occupational health costs, e.g. measures to prevent the adverse impacts of increased heat load on the health and productivity of workers;
- Costs of health research on reducing the impact of climate change, e.g. evaluation studies;
- Costs of preventing the additional cases of disease due to climate change as estimated by scenario-driven impact models.

The World Bank (2010) estimates average annual adaptation costs in the health sector for diarrhoea and malaria prevention and treatment around $2 bn over the 40-year period 2010–50. These estimates are lower than prior UNFCCC estimates (see below) The estimated adaptation costs in 2010 lie between $3 billion and $5 billion and decline over time in absolute terms to less than half that amount by 2050. Although the declines are consistent across regions, the rate of decline is faster in South Asia and East Asia and Pacific than in other regions. As a result, by 2050 more than 80 percent of the health sector adaptation costs for malaria and diarrhoeal diseases are incurred by countries in Sub-Saharan Africa.

UNFCCC (2007) has estimated costs of $4–12 billion per year in 2030 for adaptation in the health sector in developing countries. These costs represent the costs of preventing additional cases of malnutrition, malaria and diarrhoeal disease due to climate change by 2030 (low and middle income countries only, developed country costs were not estimated).

According to IIED (2009) this is an underestimate; the UNFCCC costs do not consider the full range of climate futures or the full range of disease/health outcomes; are based on optimistic assumption of steep relative decline in incidence.

Sources:

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8 Knowledge gaps

Attributing health outcomes to climate trends is inherently difficult. While the research is increasing, the evidence base remains relatively weak in relation to the complexity of the issue and the magnitude of the health risks. The majority of studies so far have focused on data from middle- and high-income countries.

All assessments to date are limited by factors including:

- The need to consider multiple, interacting and multi-causal health outcomes. The linkages between climate change and health are complex and affected by many other factors including socioeconomic status, access to health services, environmental conditions and local capacity to cope with weather-related hazards;
- The difficulty of attributing health outcomes to climate or climate change *per se*;

- The difficulty of generalising health outcomes from one setting to another, when many diseases (such as malaria) have important local transmission dynamics that cannot easily be represented in simple relationships;
- The limited availability of region-specific projections in health-related exposures and lack of research projecting health outcomes under various future emissions and adaptation scenarios from low income countries;
- The difficulty in identifying climate-related thresholds for population health;
- The limited understanding of the extent, rate, limiting forces and major drivers of adaptation of human populations to a changing climate;
- The fact that the majority of studies so far have focused on middle- and high-income countries.

There remain significant gaps in our knowledge, in particular about:

- The current and potential future impacts of climate-related risks;
- The degree of population vulnerability;
- The characteristics of vulnerable groups;
- The type of surveillance and alert and emergency management systems;
- The most useful indicators for monitoring and evaluation of the criteria for action and the comparative effectiveness of different adaptation and policies.[lxviii]

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[lxviiilxviii] Source: www.who.int/globalchange/health_policy/who_workplan/scientific_evidence/en/index.html

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