A public health approach to the impact of climate change on health in southern Africa – identifying priority modifiable risks

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Anthropogenic climate change and anticipated adverse effects on human health as outlined by the Intergovernmental Panel on Climate Change (IPCC) are taken as givens. A conceptual model for thinking about the spectrum of climate-related health risks ranging from distal and infrastructural to proximal and behavioural and their relation to the burden of disease pattern typical of sub-Saharan Africa is provided. The model provides a tool for identifying modifiable risk factors with a view to future research, specifically into the performance of interventions to reduce the impact of climate change.

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Anthropogenic climate change results from economic activities increasing the emission of greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane, which increase the heat-trapping capacity of the lower atmosphere, resulting in global warming with surface temperatures and the annual number of dry days and hot nights increasing over time. The Intergovernmental Panel on Climate Change (IPCC),[1] a scientific intergovernmental body established in 1988 and tasked with evaluating the risks of anthropogenic climate change, predicts increased frequency and intensity of extreme events (extreme heat, severe storms, droughts, and floods). The global average sea level rose by 1.8±0.5 mm per year between 1961 and 1990 and 3.1±0.7 mm per year from 1993 to 2003 as a result of thermal expansion of ocean water and melting land-based glaciers and ice-sheets. Precipitation has increased in some regions while decreasing in others.

Mitigation or primary prevention focuses on reduction of GHG emissions and modification of land use, while adaptation or secondary prevention measures aim to lessen the impact of climate change.[1] Several global conventions address mitigation. The United Nations Framework Convention on Climate Change (UNFCCC)[2] aims to stablise atmospheric GHG concentration while allowing natural adaptation without adversely affecting food production or sustainable economic development. The UNFCCC Kyoto Protocol[3] (2005) committed 37 industrialised countries to reduce various GHG. The United Nations Convention to Combat Desertification (CCD) was signed in 1996.[4] The United Nations Convention on Biological Diversity (CBD)[5] aimed at promoting sustainable development was signed by 150 government leaders at the 1992 Rio Earth Summit. Despite the adoption of these conventions by many countries, it was noted at the 15th Conference of the Parties (COP 15) to the UNFCCC[6] in Copenhagen in 2009 that observed GHG emissions already exceeded the worst-case 2007 IPCC scenario trajectories.

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Climate change and health

Climate change affects the fundamental requirements for health – safe drinking water, clean air, sufficient food and secure shelter, and has many direct and indirect adverse health impacts.[1] The impact on health results directly from extreme weather events (e.g. heat waves and floods) and indirectly from socially mediated risks (e.g. displacement, conflict, damaged infrastructure, crop failure) and/or ecologically mediated risks (e.g. food, water, vectors).[7] The World Health Organization (WHO) has estimated the global burden of disease attributable to climate change risk factors at 2000 (relative to the 1961- 1990 average base climate) as 160 000 premature deaths and the loss of 5 500 000 disability-adjusted life years based on climate-sensitive conditions such as malaria, malnutrition, diarrhoeal disease, heat waves and floods.[7,8]

Methodology

A literature review was conducted for studies relevant to climate change and health in southern Africa. A public health approach to the systematic identification of health risks involves consideration of a spectrum of risk from the most upstream climate effects to downstream biological and individual effects. Health status is examined from the point of view of the composition of the burden of disease in South Africa.[9] The complex and interacting associations between upstream and downstream risks for adverse health outcomes arising from Fig. 1 can be examined by using multivariate methods and by means of careful study design.[10] The main objective is to isolate those risks which individually or in various combinations have the greatest health impacts and which are also modifiable. This will enable the identification of the most promising interventions and the construction of appropriate surveillance systems for ongoing monitoring of climate-related health impact.

Climate-related health risks

To comprehensively consider the complex and interacting effects of climate change on health, we have drawn from existing models developed by McMichael *et al.* (2003)[11] and Eisenberg *et al.* (2007).[12] We present an adapted model (Fig. 1) which aims to assist with the identification and causal modelling of the most important modifiable climate-related risk factors (singly or in combination) for adverse health effects. Risks are considered on a continuum from the most upstream to the most proximal for human health.

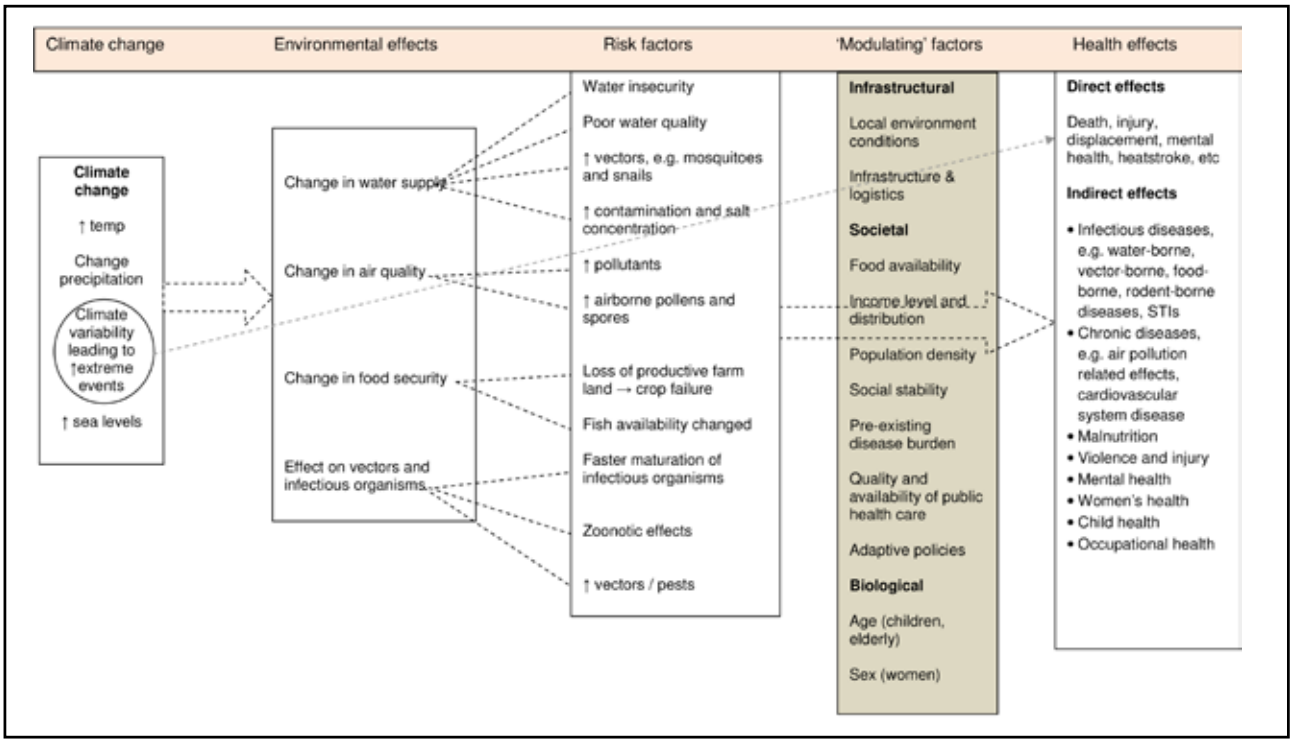

Fig. 1. Impact of climate change on health (adapted from McMichael et al.[11] *and Eisenberg* et al.[12]

Risks from the environmental effects

The combination of increased frequency and severity of droughts and floods impacts negatively on agricultural yields and vector populations.[13,14] Damage to essential infrastructure results in population displacement along with contamination of potable water by runoff and sewage.[15]

Water scarcity results in higher concentrations of salt and chemical contaminants, and rising sea levels salinate fresh water with loss of productive farm land and changed vector habitats.[14]

Higher temperatures, rainfall and humidity also affect the formation and dispersal of various chemical air pollutants and aeroallergens, e.g. ozone in the lower urban atmosphere forms more readily at higher temperatures from air-pollutant precursors.[14]

Global food yields are predicted to be negatively affected where both warming and drying are likely to occur, while fish populations are likely to move to higher latitudes and will be affected by coral reef damage, warmer waters, acidification due to increasing uptake of CO_2 and decreased consistency of river flows.[14]

Warmer conditions promote rapid multiplication of infectious agents (dengue, bacteria, protozoans) and vectors,[14] although it is unclear whether there will be a net increase in malaria.[16] Changes in the density and movement of vectors and the reservoir animal species can intensify infection by zoonoses (e.g. Rift Valley fever in Kenya), and cause malaria at higher altitudes in eastern and southern Africa.[13,14]

Factors modulating the impact of climate-related risks on health

Multidirectional interacting relationships make the causal relationships between climate change and health more complex.[17] The public health approach conceptualises health determinants, including modulating factors, as ranging from distal to proximal, or from infrastructural through social to individual behavioural and biological levels of risk (Fig. 1). These modulating determinants may behave as confounding, effect-measure modifying or mediating variables in the relationship of principal interest between climate change risks and health outcomes. Specific hypotheses about causal pathways could be modelled using these variables, taking into account a range of social, institutional, technological, behavioural and biological adaptations to environmental conditions.

Coastal, urban, low-lying areas, islands and vector border regions will be affected more than other areas.[18] The quality of water, sanitation, roads and transport logistics to cope with disaster will influence the impact of climate change.

Food-insecure, economically disadvantaged, politically conflicted countries and vulnerable populations (women, children and the chronically ill and immunocompromised) will be less able to adapt and more affected.[19,20] Conflict will arise over access to scarcer crops, land and water.The quality, availability and readiness of essential public health responses including disease surveillance, health promotion, community mobilisation, disaster preparedness, emergency service response, training of emergency and health service personnel, programme evaluation, research and innovation in respect of mitigation and adaptation are important.[17,21,22]

Children, pregnant women, the elderly and the chronically ill are more vulnerable to infectious diseases, malnutrition, heat-related illnesses, water insecurity, extreme events, effects of air pollution, and injury.[18,23-26] Women are less empowered than men in almost all societies and, as a result, are affected more than men during natural disasters – more women are killed and at a younger age than men.[27] This difference is influenced by the socio-economic status of women, and is more pronounced in countries where women have a very low social, economic and political status. Pregnant women are particularly vulnerable to various infectious diseases, including malaria and hepatitis E. Fuel and water shortages increase women's workload where they are responsible for their collection.[28]

Climate-related adverse health outcomes

Climate change will aggravate existing health problems rather than leading to new problems, although beneficial effects may also result, e.g. warmer winters in very cold regions.[1,14]

Direct effects

There is an increased risk of death, injury, and population displacement as a result of extreme climate events such as fires, droughts, hurricanes and floods. Anxiety, post-traumatic stress disorder, depression, and other mental health conditions follow trauma, loss of loved ones and property, and displacement.[14,28]

Prolonged exposure to high temperatures can cause heat-related illnesses such as heat cramps, heat syncope, heat exhaustion, heatstroke and death. More frequent and intense heat waves are associated with an increased morbidity and mortality.[25] The elderly and people with pre-existing medical conditions (e.g. cardiovascular disease, psychiatric conditions) and those on medication that impacts on salt and water balance are at great risk for heat-related illness and death.[25] Drinking alcoholic beverages, ingesting narcotics and participating in strenuous outdoor activities, e.g. manual labour in hot weather, which is a feature of much work in the developing world during summer, are also associated with heat-related illnesses.[245] Temperature extremes affect physiological functioning, mood, behaviour (accidents or aggression) and workplace productivity, especially in outdoor workers (e.g. subsistence farming) and those working in poorly ventilated, hot conditions.[29,30] An association with increased civil and military violence has been documented.[31]

Chemical and biological effects of air pollutants and allergens increases mortality from asthma and chronic lung disease.[14]

Indirect effects

These are systematically considered in the light of the major contributors to the South African national and provincial burden of disease.[32]

Infectious diseases

Waterborne enteric diseases are affected by changes in rainfall patterns which affect river flows, flooding, sanitary conditions and the spread of diarrhoeal diseases, including cholera, as well as other enteric diseases caused by enteroviruses, and hepatitis A and E. Heavy runoff after severe rainfall can contaminate recreational waters and increase the risk of human illness through higher bacterial counts. This association is strongest at beaches closest to rivers. Ear, nose, and throat, skin, respiratory and gastro-intestinal illnesses are commonly associated with recreational swimming in fresh and oceanic waters. Other diseases include hepatitis, giardiasis and cryptosporidiosis.[15]

Vector-borne disease distribution can be adversely affected through faster reproduction of vectors and pathogens.[13] For southern Africa, however, the net climate change impact on malaria has been estimated to be neutral,[16] while dengue fever, tick-borne encephalitides and plague are predicted to increase.[13]

Food-borne infections (e.g. salmonella) have been found in the UK, Australia and Canada to be associated with short-term (e.g. weekly) high temperatures.[33] This effect would be aggravated in less-developed settings.

Sexually transmitted infections (STIs), specifically HIV in southern Africa, are associated with population displacement, poverty and dislocated communities, gender violence, transactional sex, commercial sex work, increased partner numbers, and increased risk-taking behaviours, all of which may be aggravated by climate change.

Violence and injury

As a consequence of worsening climate and environmental conditions, there will be increased immigration and refugee pressures on the environment and on neighbouring countries. The demographic disruption and associated social tension will be associated with adverse health effects, which include increased interpersonal violence.[14] In addition, damaged transport infrastructure and poor weather conditions or increased temperature may increase the incidence and severity of motor-vehicle-related accidents. There is evidence that higher temperatures are associated with greater civil and military violence.[31]

Mental health

Anxiety, depression, post-traumatic stress disorder and suicide may result from displacement, loss of family members, disabling injuries, lost livelihood (e.g. long-term drying in rural regions) and impoverishment, and are indirect consequences of climate change.[28] Substance (especially alcohol) misuse and abuse are also more prevalent among displaced populations and populations subject to extreme environmental or climatic stressors.

Chronic diseases

There is an increased risk of respiratory illnesses from the higher ground-level ozone and other air pollutants. Increases in airborne pollens and spores can exacerbate asthma, chronic obstructive pulmonary disease (COPD) and other respiratory allergic conditions. Cardiovascular system (CVS) disease (e.g. cardiac failure, stroke) worsen as a result of air pollution, and renal disease is associated with heat waves (for example, kidney stone disease associated with dehydration and increased hospitalisations for acute renal failure, or renal damage due to chronic dehydration).[29,34]

Malnutrition

Increased risk of malnutrition results from impaired agriculture or loss of rural livelihoods. The WHO's estimate of disease burdens already attributable to climate change in the year 2000 identified malnutrition as the pre-eminent component of health loss.[8] Most of that estimated loss (via premature deaths, stunting and disabling infection) was in young children in developing countries.

Women's and child health

Women and children are more vulnerable to effects of heat, water insecurity, extreme events, malnutrition, and infectious diseases[19,23-26] Women's lower social standing within communities results in a greater economic stress and resultant direct and indirect health impact from climate changes.

Occupational health

Physical hazards due to temperature extremes can cause heat illness and loss of productivity (most subsistence agriculture takes place in hot parts of the globe where there is no possibility of air conditioning) or cold injury and loss of productivity as a result of encumberment with many layers of clothing.[34,35] Chemical hazards from the effect of wildfires in dry and hot conditions, or smog in cold weather with temperature inversions, can have serious cardiorespiratory effects. Emergency and health personnel are particularly at risk from stressful social and environmental conditions and infection hazards.

Conclusions

A public health approach to climate change considers multilevel determinants of health outcomes and thereby outlines a rich field of study for determining overall and specific risks for adverse outcomes. A framework for constructing analytic models based on this approach is provided, and may be used to determine priority modifiable risks responsible for the greatest contribution to the climate change-specific burden of disease in different local settings. Constant surveillance of climate-related health and associated risks allows for intelligent planning to ensure that mitigation and adaptation happens in the most effective and cost-efficient manner to sustain health status into an uncertain future.

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Responding to climate change in southern Africa – the role of research

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Projections show that the effects of climate change in Africa will not be uniform over the region. The region is extremely vulnerable to climate change because of poverty, a high pre-existing disease burden, fragmented health services and water and food insecurity. Despite the consensus that locally relevant information is necessary to inform policy and practice related to climate change, very few studies assessing the association between climate change and health in southern Africa have been conducted. More comprehensive information is therefore urgently needed for the southern African region to estimate the health risks from projected future changes in climate.

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Evidence is that the southern African region (Fig. 1)[1] is experiencing an increasing frequency of hot days and a decreasing frequency of extremely cold days. Rainfall trends are variable, but evidence points to an increased interannual variability, with extremely wet periods and more intense droughts in different countries. Projections show that changes will not be uniform over the region; the central, southern land mass extending over Botswana, parts of north-western South Africa, Namibia and Zimbabwe is likely to experience the greatest warming of 0.2 - 0.5°C per decade. Frequency of extremely dry winters and springs will increase by roughly 20%, while the frequency of extremely wet summers will double. Warming is also predicted to increase the frequency and intensity of tropical storms in the Indian Ocean.

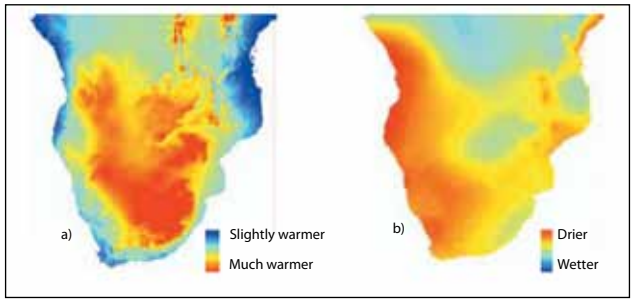

Fig. 1. Projected climate change in southern Africa: HADCM3 climate model projections of changes in (a) temperature and (b) precipitation for 2050 relative to mean conditions over the 1961 - 1990 period, under the IPCC SRES A2 (high emissions) scenario.[1]

The region is vulnerable to climate change because of poverty, a high pre-existing disease burden, fragmented health services, and water and food insecurity. Despite the consensus that locally relevant information is necessary to inform policy and practice related to climate change, very few studies assessing the association between climate change and health in southern Africa have been conducted.[2-4] Existing research focuses on infectious diseases – particularly malaria. Little work has been done on attributing disease burden to climate change in the region. Furthermore, an overview of health considerations in the National Adaptation Programmes of Action for climate change in least-developed countries and small-island states found that health was not seen as a priority, as most activities focused on biodiversity and agricultural activities.[5] Very few institutions specialising in climate change and health were identified.

The health effects of climate change are not uniform and will be influenced by local environmental conditions, socio-economic circumstances, the extent of adaptations implemented to minimise the full range of threats to health, and other modulating factors.[6] The IPCC Working Group 2 report (2007)[7] shows that the health consequences of climate change will fall primarily on low-income, poorly resourced and geographically vulnerable populations. Importantly, planning and action will need to be intersectoral, draw on local data, and involve local and regional authorities and health care providers.

Framework for responding to climate change

Corrective activities may be grouped into mitigation, adaptation, education and training, and raising awareness. Research is central to all these, as it will inform identification and assessment of effects, comparison of interventions, and determination of best practices.

Regarding mitigation, 5 African countries are responsible for most of Africa's greenhouse gas (GHG) emissions, with South Africa by far the greatest emitter, responsible for 39% of the continental total – making GHG emissions in the SADC region relatively higher than in other regions of Africa.[8] This issue is a high priority for intervention and will depend on national energy policy.

Adaptation needs to be underpinned by surveillance for climate-related health risks[9] including early adverse weather alerts and disaster preparedness. Beginning with the infrastructural, urban planning and housing design needs to consider climate- and insect-proofing, enhanced infectious disease control includes vaccines, vector control, case detection and treatment. Community partnerships are required to identify and solve health problems, including neighbourhood watch schemes aimed at the elderly and children.

Table I. Research directions for preventing adverse health consequences of climate change

Research task	Proposed epidemiological studies for SADC region with examples
Clarify relationships between background climate variation and health outcomes	Incidence of heat-related illness in outdoor workers in plantation agriculture[11,12] Effect of background climate variation on food security and health (e.g. malnutrition and diarrhoeal disease in under-5s) using existing secondary or primary meteorological, agronomic data and health data
Estimate, statistically, current burden of disease attributable to climate change	Using available secondary data (SADC burden of disease data exist and are currently being updated) to perform a comparative risk assessment of the burden of disease from climate change[13-16]
Seek evidence of actual current health impacts	Perform a study of deaths from diarrhoea among under-5s in relation to the change in climate (e.g. drying) Examine the incidence of heat-related illness in outdoor workers in plantation agriculture in relation to extreme heat events as measured by the wet bulb globe temperature (WBGT)[11,12] Use estimates of risk obtained from ecological and from more detailed epidemiological studies to model the impacts of various climate change scenarios over time. Consider the roles of different predictors of the health outcome in complex regression models taking into account mediated and direct effects[16] Predictors include the ability of the health system to detect and respond to increased adverse health outcomes
Develop scenario-based modelling to project future risk (including handling complexity & uncertainty)	Use scenario planning methods for high-level modelling and prediction of likely futures
Estimate health co-benefits of actions to avert/reduce further environmental change	Planting drought-resistant crop strains may have beneficial effects through a reduced need for agrichemicals Public transport systems may be more energy efficient than private motorised transport; promote cycling and walking
Evaluate health-protecting ('adaptive') actions	Evaluate the result of introducing a drought-resistant staple crop on rural malnutrition and child health outcome
Monitor for unintended consequences of adaptation	Study the effects of a new drought-resistant strain of staple crop on whether more chemical hazards to agricultural workers and residents emerge, or whether unintended adverse nutritional effects ensue, or whether the new strain may displace existing staples with negative overall nutritional impacts

Mitigation and adaptation interventions should be monitored and evaluated for effectiveness and efficiency.

Climate change and health should be incorporated as part of undergraduate and postgraduate public health education curricula, and appropriate training packages developed. Special efforts should be made to recruit trainees from areas at greatest risk from the health effects of climate change.

Awareness should be raised through informing, educating and empowering the public at large, along with policymakers and all relevant stakeholders about the health risks of climate change as well as primary and secondary prevention strategies which can reduce the impact.

Research in support of adapting to climate change

Research should aim to facilitate the reduction of both global and local climate change health risks via aetiological studies, risk assessments, scenario planning of likely future health risks, and evaluation of adaptive interventions. More comprehensive information is needed for the southern African region to estimate the health risks from projected future changes in climate. Epidemiological studies are needed to identify climate-health relationships, to quantify them, and to identify high-risk groups or communities. Table I provides a framework for research provided by McMichael.[10]

To gain a more complex understanding from epidemiological modelling, it is important to incorporate confounding or interacting, non-climate variables. Scenario planning should incorporate information about trends in other determinants of health outcomes for which future extrapolations are considered feasible (e.g. demographic trends in age structures); likely future contextual conditions (e.g. uptake of domestic air-conditioning by 2050); the advent of relevant vaccines and likely consequent population immunity levels; and deliberate 'adaptive' changes (e.g. mosquito control programmes, heat-wave warning systems, flood protection measures).

The health sector itself requires research attention as a result of the environmental effect of resource use and waste generation, and the need for sustainable health sector practices. Health economic analysis of climate-related health impacts, along with research into communication strategies for climate-related health issues, is an important research focus.

Pressing action and research priorities include the assessment of the climate-related burden of disease in southern Africa, and the identification of appropriate adaptations for which there is existing evidence of effectiveness and cost-efficiency elsewhere, particularly parts of the globe with similar climate-change scenarios.

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