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Literature Review Assessing Climate Change Risks and Impacts on the Health Sector in the Western Cape, South Africa

Provincial Strategic Goal 4: Enable a Resilient, Sustainable, Quality and Inclusive Living Environment

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ABSTRACT

Introduction: The impacts of climate change are cross-cutting and will adversely affect public health. The Western Cape government (WCG) of South Africa in partnership with the Cape Higher Education Consortium (CHEC) requested and funded a review of literature assessing climate change risks and impacts on the health sector in the WC. The aim of this project was to review the literature and conduct a gap analysis of WC-specific health impacts and risk factors by drawing on global, national and provincial knowledge to better understand what health impacts the WCG can anticipate and prepare for.

Method: A stepwise methodological framework for the literature review was developed by the University of Cape Town (UCT) research team. This unique comprehensive framework allows for comparing global research findings with national and local research to highlight gaps and research needs at the local level. The framework employs a six-step approach which considers WC climate projections with associated health impacts, provides reference to vulnerable populations whilst also addressing local burden of diseases and draws knowledge from the global and national setting. A further analysis of the research gaps involved sending out a climate change and health research questionnaire to WC researchers (N = 292) to identify past, current and planned future research. A review of climate change and health intervention strategies was also undertaken with global adaptation examples provided.

Results: Direct, climate-related risk factors were identified. Although some regions of the WC might fall outside of the general projections, overall, the WC is likely to experience a hotter and drier future with further increases in sea-level rise and a greater frequency and intensity of extreme weather events. Multiple climate change-related indirect risk factors were categorized as falling into two main areas: environmental (e.g. air pollution), or social (e.g. urbanisation). Generalized projected health impacts in the WC resulting from climate change include: temperature-related deaths and illnesses; cardiorespiratory, renal, infectious, vector-borne and water-borne diseases; mental ill-health; hazard-specific deaths and injuries; malnutrition; allergies and social conflicts. The WCCCRS (2014) update should include the following climate change-related adverse health outcomes: injury, NCDs, mental ill-health, food and nutrition insecurity-related diseases, water-borne diseases and reproductive health. The gap analysis, including the results from the research questionnaire (N = 31 WC researchers consented to partaking in the questionnaire), of health impacts revealed that the WCG should further prioritize climate change research in many areas with the most urgent being: heat strain in outdoor workers, violence and the urban heat island effect, pests and diseases, child and gender-focused research and reviewing the provincial burden of disease within the context of climate change. The WCG should strengthen interventions to address climate change impacts on health and should incorporate climate change risk communication into existing strategies. The WCG would benefit by learning from and building on global adaptation strategies Identified in this study.

Conclusions: Although the WCG has made several efforts to include health in climate change policies, the key health issues for the WC are not addressed both in policies and adaptation interventions. Additionally, the impacts of climate change on human health should feature more prominently in health professional's education curriculum. The WCG should create adaptation and mitigation strategies and projects that are viewed through a health lens at the initial formation stages of projects such that there is "health and climate change in all policies" approach. There is a great need for further research in the WC-specific priority focus areas identified in this review through the gap analysis.

INTRODUCTION

Climate change has been deemed the “greatest global health opportunity of the 21st century” (Watts et al., 2015) and the impacts of climate change on human health are featuring more prominently in global discussion. Considerations of climate change and health at the regional level, particularly in Africa, are limited (Baker et al., 2012; Pasquini et al., 2013). Climate change is a cross-cutting concern of many sectors, especially health, and developing locally appropriate regional health strategies is often challenging for governments of low- and middle-income countries (LMICs), particularly as there is a plethora of information available from a global perspective, which may not be applicable to, or translated for, local conditions.

In South Africa, the current national documents and assessments of climate change impacts on health rarely consider local regions or provinces, and therefore the WCG requested evidence for local decision-making on climate change and health policies. The current provincial climate change response strategy (i.e. the WC Climate Change Response Strategy [WCCCRS] of 2014) has a brief section on health which is not comprehensive due to the paucity of available WC-specific research as well as government’s limited access to published academic articles. Thus, a thorough literature review and gap analysis highlighting key climate change and health issues for the WC is needed.

This literature review is a response to a call from key stakeholders in the province, namely the WC Department of Health (WC: DoH) and the WC Department of Environmental Affairs and Development Planning (WC: DEA&DP), for an updated literature review to identify the anticipated health impacts of climate change and the required responses of the WCG.

PROJECT OBJECTIVES

The objectives of this research conducted under the Division of Environmental Health at the University of Cape Town (UCT) were:

- 1) To review the global, national and provincial literature on the likely climate change health impacts, risk factors and vulnerabilities anticipated for the WC;
- 2) To identify climate change and health gaps in the current WC climate change response strategy and WC-specific research;
- 3) To identify adaptation and mitigation intervention strategies and gaps around climate change and health in the WC.

METHODS

The following methods were employed to address the three study objectives:

Objective 1

A stepwise methodological framework for the literature review was developed by the University of Cape Town (UCT) research team for meeting the first and second project objectives (Figure 1). Such a framework has not previously existed and is comprehensive to compare global research findings with national and local research to highlight gaps and research needs at the local level. The framework employs a six-step approach and considers local climate projections with associated health impacts, provides reference to vulnerable populations whilst also addressing local burden of diseases and draws knowledge from the global and national setting.

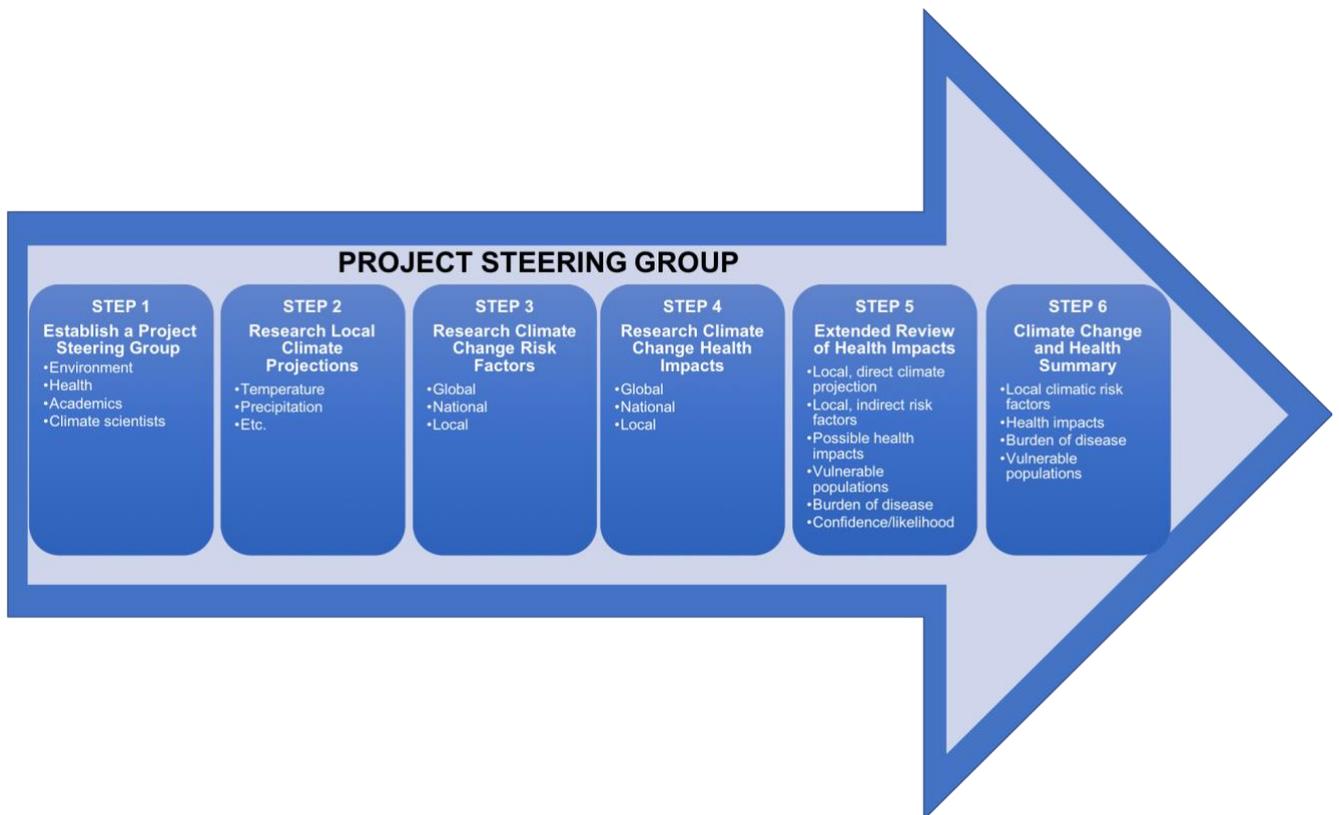


Figure 1: University of Cape Town’s methodological framework to assess Western Cape climate change risks and health impacts.

This framework incorporates local climate change projections with anticipated risk factors and health impacts to provide both a detailed and generalised summary of how local governments need to adapt and respond to climate change impacts on health. This method facilitates engagement and action from stakeholders through the Project Steering Group (PSG). UCT’s methodological framework was developed to guide this literature review but may also be useful for LMICs in developing local adaptation strategies and priorities.

The steps for conducting a comprehensive literature review, as outlined in Figure 1, are described below.

Step 1: Establish a Project Steering Group (PSG). At the onset of the project, a PSG consisting of relevant stakeholders was established to provide input into the methodology, comment on the findings, provide grey literature resources and relevant contacts. The group met seven times during the duration of the project from April 2017 to April 2018 (meeting dates: 8th of May 2017, 12th of June 2017, 5th of July 2017, 8th of August 2017, 21st of September 2017, 5th of December 2017, 2nd of February 2018). PSG members included UCT public health specialists and climate scientists, and provincial government staff from the WC: DEA&DP and the DoH. Academics and government staff that were involved in writing the proposal and call were invited as members on the PSG. A full list of the seven PSG members can be found in Appendix 1.

Step 2: Research Local Climate Projections. WC climate projections were obtained by climate scientist experts from the African Climate and Development Initiative (ACDI) and from grey literature sources such as the Climate Systems Analysis Group (CSAG) (Blamey et al., 2014), DEA&DP (2016) and DEA&DP (2016b). The ACDI is a UCT initiative which actively responds to Africa’s climate change and development challenges. Local climate projections from these sources were discussed with the PSG who provided expert opinion as to the most appropriate climate projections for the province.

Steps 3 and 4: Research Climate Change Risk Factors and Health Impacts. Indicators and key words of climate change-related health impacts and risk factors were identified from reference documents to determine climate change risks (Appendix 2) and health impacts (Appendix 3), as well as to conduct a gap analysis. These reference documents were selected because they were peer-reviewed, published by a reputable source and were largely considered the gold standard report for the region.

The **reference document** chosen to represent **global research** was from the Lancet Commission on Health and Climate Change (Watts et al., 2015). The Lancet has a long-standing reputation as being a leader on health research and the Commission on Health and Climate Change was specifically created to identify the possible impacts of climate change on health to ensure that necessary policy responses are based on the highest attainable standard of healthcare. The **reference document** chosen to represent the **African continent** in general was the Africa Chapter (Niang et al., 2014) from the Intergovernmental Panel on Climate Change's (IPCC) latest report (IPCC, 2014). The IPCC is the benchmark report for the region on climate change. The **reference document** chosen to represent research covering **Southern Africa** was a paper by Myers and colleagues published in the South African Medical Journal (Myers et al., 2011). The paper provides a thorough overview of how climate change is likely to impact upon public health, is peer-reviewed, and has been widely cited. The **reference document** chosen to represent **South Africa** specifically was the Long-term Adaptation Scenarios (LTAS) technical report on Human Health (DEA, 2013). The LTAS is a flagship research programme facilitated by the national Department of Environmental Affairs and was developed to respond to the South African National Climate Change Response White Paper. Finally, the **reference document** chosen to represent a summary of information for the **local region** was the WCCCRS (WCCCRS, 2014) as it is the current climate change response strategy for the province. Guidance on the selection of the documents was also provided by the PSG.

Step 5: Extended Review of Health Impacts. A thorough analysis and review of health impacts is difficult if an adequate search strategy is not employed. Therefore, the indicators and key words identified in Steps 3 and 4 provided the structure for the search strategy for the literature review. Each risk factor was searched against each health impact, for example, "flooding AND depression" and "food security AND depression".

As this step was labour intensive and beyond the scope of the project objectives, only temperature and health outcomes were researched (Appendix 4) to provide an example of what type of research could be conducted in the future. Therefore, completing the extended search for all climatic variables and risk factors is recommended for future research.

Occasionally, upon searching for research articles additional health impacts would become apparent such as hand, foot and mouth disease that was not mentioned in any of the reference documents. These health issues were still included in the review but were highlighted as being identified through UCT's search (Appendix 3). Articles were excluded from review if they were not peer-reviewed and published in English. The following search domains were used: PubMed, Scopus and Google Scholar (first 10 pages). To avoid presenting the results of this step in an unordered list, health implications were categorized in relation to the region's burden of disease (Appendix 4). It was also necessary to comment on the degree of certainty to give an indication of prioritization; the IPCC confidence intervals were useful for this purpose (Appendix 4).

By presenting stakeholders and decision-makers with an extended review of adverse health outcomes, there was a risk of inducing fatalism which can lead to inaction or disengagement (Clayton et al., 2017). Therefore, it was vital to conduct Step 6 which presents a summary of the main health impacts resulting from climate change.

Step 6: Climate Change and Health Summary. Creating a summary of climate change-related health impacts for the WC was the final step in our framework to present the broader distribution of information in a concise and accessible format.

Whilst indirect risk factors are important variables that will influence health outcomes, only climatic risk factors were presented in the summary for the WC linked to regional climate projections. We felt that it was also important to highlight vulnerable populations and the region's burden of disease to indicate which diseases on the burden of disease list (Morden et al., 2016) were likely to be affected by climate change. The IPCC's (2014) Chapter 11 on health provided the summary of direct climate and weather on health which was useful for obtaining summary data on heat- and cold-related impacts as well as floods and storms. The WHO Atlas of Health and Climate (2012) was used for obtaining summary data on floods, cyclones, drought and heat stress. For other climatic risks, such as sea-level rise, it was necessary to search for a dedicated review using the following search terms in PubMed and Scopus: "health sea level" and filtering by Review. A challenge in creating a summary was highlighting the strength of relationships between climate projections and health impacts. For example, the relationship between an increase in ambient temperature and the occurrence of heat stress (Semenza et al., 1996) is strong and well researched (IPCC, 2014) compared to the relationship between increased ambient temperature and mental health (Likhvar et al., 2011). Nonetheless, both health outcomes were identified for adaptation and strategic planning and future research could further explore the strength of relationships (risk factors and health outcomes) for comment on strategic priorities for the region.

Objective 2

To fulfil the second objective of the study (identify climate change and health gaps in the current WCG climate change response strategy and WC-specific research), a health-focussed gap analysis was conducted to determine the research gaps in the WC. This was achieved through an online questionnaire developed by the project team and reviewed by the PSG (Appendix 5). The questionnaire aimed to determine what climate change and health research for the province had been done, was currently taking place and identify research plans. Researchers were also asked what topics they felt should be research priorities for the province. The questionnaire was sent out to researchers (N = 292) in October 2017 who were potentially involved in research on climate change and health in the WC as identified through PSG members and a Public Health Association of South Africa database.

Objective 3

To fulfil the third objective of the study, an extensive search of WC climate change and health interventions was undertaken using a five-stage research approach detailed in the Interventions Section of this report. The five stages included: i) an analysis of the WC climate change database, ii) an analysis of the current state of WC key climate change documents, iii) a Google search for WC climate change interventions or projects, iv) a Google search for national climate change interventions or projects, v) a Google search for global climate change interventions or projects.

RESEARCH FINDINGS

A summary of the findings from the literature review is presented below. The findings are divided into various risk factors (direct and indirect) and health impacts (direct and indirect) that are relevant to the WC. As the risk factors will result in various health outcomes, these are discussed first to contextualise the relevant issues with the health outcomes.

Findings: Potential Western Cape Risk Factors

As shown in Figure 2 below, risk factors can either be direct or indirect and, if indirect, can be further subdivided into environmental or social risk factors.

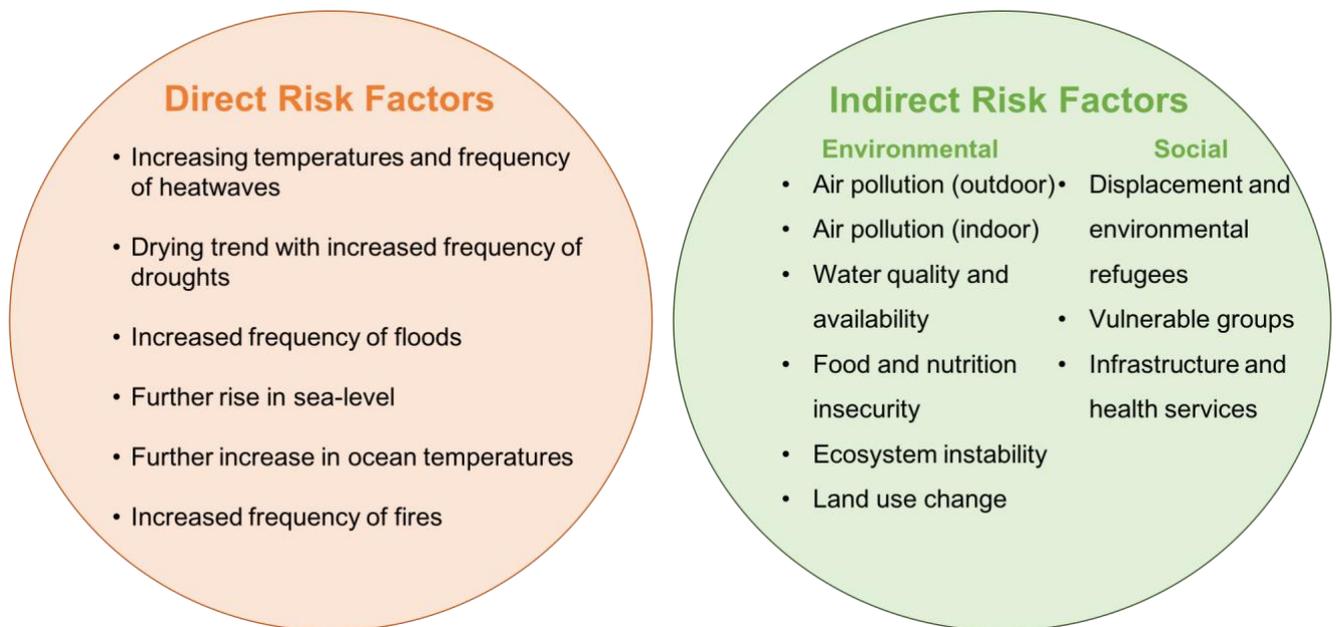


Figure 2: Climate change risk factors for health in the Western Cape.

Direct Risk Factors

To have a picture of what potential health concerns could be linked to climate change, it is important to know the predicted climate for the WC. Climate projections are often the result of analysis from historical observations, global climate models (GCM) and downscaled models that take local topography into account. Climate projections for the WC were challenging to assess due to the geographic location of the province, long coastline with ocean currents of differing temperatures, varied landscape (mountain ranges, oceans, inland plateau areas) and variable weather patterns arising from the Southern Ocean (Blamey et al., 2014; WCCCRS, 2014). Generally, models agree on a warming trend with possible shifts in seasonality (Blamey et al., 2014; WCCCRS, 2014; DEA&DP, 2016). Based on the literature, the following are WC climate projections that could impact on health (Step 2 of Methodology).

Temperature

Temperature projections for the WC suggest a continued warming trend of uncertain magnitude with the greatest impact during summer months (Blamey et al., 2014; WCCCRS, 2014). There are likely to be more frequent extreme heat days, with a decreased number of cold days annually (WCCCRS, 2014). It is projected that the increase in maximum and minimum temperatures will be greater throughout the drier inland and northern areas of the WC with smaller increases throughout the southern Cape due to the influence of sea surface conditions and the prevailing winds (Blamey et al., 2014). Summer maximum temperatures are projected to increase by 1.5 °C to 2.25 °C throughout the region with some models projecting an increase as high as 3.0 °C by 2060 (Blamey et al., 2014). Summer minimum temperature increases are projected to range from 1.0 °C to 2.0 °C reaching 3.0 °C by 2060 in some models (Blamey et al., 2014). By the year 2100, temperatures across Africa are likely to increase by 2 °C to 4 °C under different representative concentration pathways (RCP) of high emission (of greenhouse gases) or low emission (of greenhouse gases) scenarios (IPCC, 2014). These global projections are accompanied by an increased frequency and duration of extreme heat events such as heatwaves (IPCC, 2014). An increased temperature and frequency of heatwaves directly impacts on human health leading to increased mortality and morbidity as is discussed in the Direct Health Impacts section below.

Rainfall

Whilst projections of both temperature and rainfall have associated challenges, rainfall patterns are more difficult to predict due to greater spatial and temporal variations as well as influence of the local topography, such as mountains (Blamey et al., 2014). Although projections are equivocal, it is likely that there will be no significant changes in rainfall over the short-term, however, over the longer term a drying trend is projected (DEA&DP, 2016b). It is anticipated that the drying will occur in the WC except for the western and southern mountain regions that may experience wetter conditions (WCCCRS, 2014). There is also the possibility of more droughts due, in part, to increased evapotranspiration resulting from higher temperatures (DEA&DP, 2016). There are also concerns that whilst total rainfall may remain unchanged, at least in the short-term, the number of rainfall days might decrease and the intensity of rainfall (classified as ≥ 10 mm per day) might increase, with longer time periods between intense rainfall events (Blamey et al., 2014; WCCCRS, 2014, DEA&DP, 2016). Intense rainfall events with storm surge can also result in excessive coastal flooding. There is also the possibility of increased hail storms throughout the region (DEA&DP, 2016; DEA&DP, 2016b). Globally, under RCP 8.5 (high emissions scenario), it is predicted that there will be a greater contrast between wet and dry seasons and regions, with large scale rainfall patterns difficult to project (IPCC, 2014). However, even on a global scale, estimates show that the WC will be a region vulnerable to experiencing severe droughts by 2100 (Dai, 2011). An increased frequency of extreme weather events such as droughts and floods for the region impact on health directly (such as through injuries and burns) but also indirectly (such as through an increase in water-borne diseases) and is discussed in detail in the section below: Direct Health Impacts.

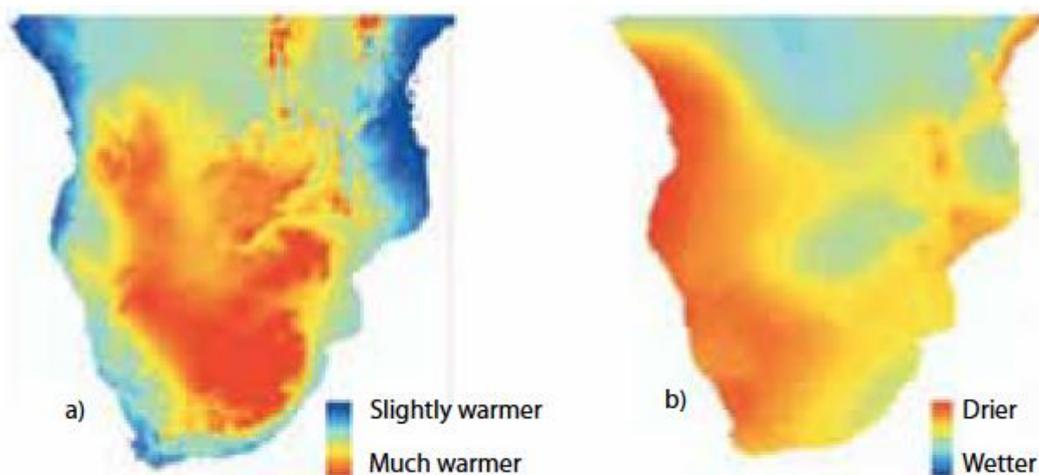


Figure 3: Temperature (a) and precipitation (b) projections under a high emissions scenario for Southern Africa for 2050 relative to the 1961 – 1990 mean conditions (Myers et al., 2011).

Sea Level and Ocean Temperatures

Sea-level is projected to rise further, increasing the risk of coastal erosion and possible salinization of groundwater and coastal soils (WCCCRS, 2014; DEA&DP, 2016; DEA&DP, 2016b). As a result of melting glaciers and ice sheets and the warming of oceans, the global average sea-level is projected to rise by 45-82 cm by 2100 under an RCP8.5 scenario (IPCC, 2014). It is likely that there will be increased frequency of storm surges resulting in an increased susceptibility to flooding (WCCCRS, 2014; DEA&DP, 2016; DEA&DP, 2016b). Average ocean temperatures are projected to increase further (IPCC, 2014) and although the IPCC has low confidence in projecting future storm surges (IPCC, 2014), these have been correlated with increased ocean temperatures and intensified cyclone activity which directly (e.g. injury) and indirectly (e.g. cholera outbreaks) impacts on human health (Emmanuel, 2005; Dasgupta et al., 2009).

Wind, Smog, Fire

Wind velocity is likely to increase in the WC (DEA&DP, 2016; DEA&DP, 2016b) and there are projections of increased smog (South Africa's Draft 3rd National Communication to the UNFCCC, 2018). Many diseases are affected by changes in wind (e.g. meningitis) and levels of smog (e.g. asthma) and thus is a concern for the health sector. There is a greater risk of fire incidents that may increase in extent and severity due to hotter and drier conditions, increased evapotranspiration, longer dry spells and increased wind speeds (WCCCRS, 2014; DEA&DP, 2016; DEA&DP, 2016b). In 2017, similar conditions resulted in large fires around the Knysna area. Fires lead to loss of life, can have devastating impacts on social activities and livelihoods, can adversely affect mental health resulting in the need for trauma counselling, and may result in an increase in morbidity as discussed in the section below: Direct Impacts on Health.

The long-term projection (to 2100) of a hotter and drier future for the WC with further increases in sea-level rise and more extreme events such as heat waves, droughts, floods and fires presents several health challenges requiring adaptation strategies. This is particularly the case for vulnerable populations. Specifically, climate variability in the WC will result in both direct and indirect risk factors that will need to be addressed. Suggested interventions from the global sphere are presented in the Interventions section below with examples listed in Appendix 11.

Indirect Risk Factors

The local climate change-related risk factors are listed below (Step 3 of Methodology). Climate change-related risk factors for human health that are not directly the result of climate or extreme weather events but are rather indirect risks include issues that we have grouped within two broad areas: environmental and social. Often an indirect risk factor might span both areas. Any adaptation strategy for addressing health impacts of climate change in the WC will need to include addressing these risk factors so as not to undermine the efforts of the strategies.

Environmental

Environmental risk factors impact on health and can be categorized into air pollution (outdoor and indoor), water quality, food insecurity and ecosystem stability.

Air Pollution (Outdoor)

Air pollution is a risk factor commonly associated with climate change and the health impacts primarily include cardiorespiratory and cerebrovascular disease (Wichmann & Vuyi, 2012). The study completed by Wichmann and Vuyi (2012) found that, in Cape Town, there was an increased risk of cause-specific mortality (cardiovascular, cerebrovascular and respiratory disease) associated with air pollutants such as PM₁₀, NO₂ and SO₂ particularly during the warm season. Men and the elderly (above 60 years old) were more vulnerable, as well as those living within 10km of the measurement site. A changing climate of warmer weather and altered precipitation frequency might alter the potency of air pollutants such as PM₁₀ and also affect dispersion, pollutant formation and transport (Hetland et al., 2005; Watts et al., 2015). Furthermore, temperature inversions trap pollutants in the cold air close to the ground when warm air overlays the cold air. During warmer weather, individuals often spend more time outdoors which might also contribute to worse health outcomes in warmer weather (Wichmann & Vuyi, 2012). With increased greenhouse gas emissions contributing to greater air pollution, ocean acidification is likely to occur through increased oceanic absorption of carbon dioxide (Raven et al., 2005). Ocean acidification will affect the health of people living in the coastal province of the WC. One mechanism of adverse health effects is related to reduced fishing activity and production, leading to undernutrition and perhaps a loss of livelihoods through decreased aquaculture and tourism thereby manifesting socio-economic despair (Barton et al., 2012; IPCC, 2014). The despair and a loss of livelihood places individuals in a poverty trap, increasing their vulnerability to adverse health consequences including poor mental health.

Air Pollution (Indoor)

Indoor air pollutants resulting from climate and weather variability include mould (Beggs, 2004), dust (Prospero & Lamb, 2003) and aerosols (Ramanathan et al., 2001). Mould is likely to become more prolific in the WC as a result of increased flooding events (Solomon et al., 2006). Mould is currently not addressed in the WC strategies but could significantly impact on respiratory health, particularly of the urban poor living in townships prone to flooding of houses. Another mechanism that indoor air pollution might affect health would be the burning of polluting indoor fuels for cooking in communities that have been displaced by climate change impacts on livelihoods for example, unemployed and seasonal agricultural workers. Extreme weather events might also result in power outages and individuals subsequently burning polluting indoor fuels during these times.

Water Quality and Availability

Climate change and extreme weather events are projected to disrupt adequate supply of clean drinking water in the WC. This has severe implications, not only for adequate nutrition, but also health risks resulting from bacterial growth, loss of agricultural activities (again placing individuals at risk of falling into a poverty trap as has been evidenced in the 2015 to 2018 drought in the province), contamination of water sources by run-off and sewerage and other contaminants including chemicals and agricultural pesticides (Lipp et al., 2002; Patz et al., 2008). Discussed in detail below, increased water temperature can provide conditions favourable to bacterial growth and replication possibly increasing the proliferation of water-borne diseases (Epstein et al., 1994; Colwell, 1996). Water (and food) scarcity as a result of climate change might also lead to violence and human conflict. For example, Gleick (2014) provides a detailed account of water scarcity within the context of climate change-related drought events in Syria and acknowledges that although socio-political and religious factors were primary determinants of the conflict, water scarcity directly impacted on Syria's economic deterioration which fuelled the conflict. Recently the WC has been drought-stricken and violent acts have occurred; increased security has therefore been necessary at natural water collection points throughout the city to ensure the safety of individuals when collecting water late at night and early in the morning (Chambers, 2018; Roelf, 2018).

Food and Nutrition Insecurity

Sub-Saharan Africa has been deemed the most vulnerable region globally to climate-change induced food insecurity (Kotir, 2011) and the impacts of climate change on food and nutrition insecurity have been deemed the greatest threat of climate change to human health (IPCC, 2014). Climate change and extreme weather events will impact food security and food quality through reduced staple crop yields and productivity, food affordability and accessibility, loss of rural livelihoods and agricultural practices, reduced soil fertility, reduced fish stocks and extreme seasonal variability (Jones & Thornton, 2003; Kotir, 2011; Knox et al., 2012). It is important to also consider the impact of climate change on nutrition insecurity and diet diversity, namely the reduced production and elevated prices of nutritious foods such as fruits and vegetables as a result of a changing climate (Dangour et al., 2015). These risk factors will have implications for human health and child development through malnutrition, food-borne diseases, mental ill-health and exacerbating infectious diseases. In the WC, 13.2% of households ran out of money in 2016 to buy food according to the 2016 Community Survey (WCG, 2016). Although this was below the national average of 19.9%, it must be noted that climate change will exacerbate this statistic and more families will be at risk of food insecurity in the future, with severe implications for human health and child stunting. Notably, climate change could also increase the percentage of children in the WC who are currently overweight (18.2% for boys and 19.1% for girls) through nutrition insecurity and food price shocks on fruits and vegetables in the future and consequent over-consumption of nutrient-poor and fattening carbohydrates and processed foods (Dangour et al., 2015).

With increasing temperatures, correct food storage refrigeration and cold-transportation become more important in avoiding food-borne diseases such as salmonellosis, as there is a linear relationship

between temperature and salmonellosis above 6 °C (Kovats et al., 2004). Moreover, livestock also have physiological limits and can be affected by debilitating heat stress (Thornton et al., 2009). Livestock can also be affected by vector-borne, animal-specific diseases such as the Bluetongue virus, a notifiable animal disease in the WC that killed approximately 300 ewes on some WC farms in the first few months of 2011 (Veterinary Services WC, 2011). The virus mainly affects sheep and its incidence has been associated with varying temperature as well as heavy rainfall following droughts (Wittmann & Baylis, 2000; Baylis & Githeko, 2006). It is therefore considered a climate change-related risk factor of notable importance for the WCG due to the projected disruptions to the water cycle expected for the province.

Ecosystem Stability

Ecosystems and vector ecology are likely to be disrupted by a changing climate and will impact on human health through food insecurity, infectious diseases and loss of livelihoods (aquaculture) (Rijnsdorp et al., 2009; Keesing et al., 2010; Iglesias et al., 2011). Specifically, there is projected to be a loss of biodiversity (Keesing et al., 2010) and increased desertification (Braham & Dotwana-Zona, 2017), with potential ecosystem collapse in some areas affecting fish species and populations (Rijnsdorp et al., 2009). Eutrophication, increasing water temperature and ocean acidification can increase the production of harmful algal blooms (IPCC, 2014). Along with the example of cholera mentioned in detail below, harmful algal blooms are considered dangerous to human health as the blooms produce toxins that affect shellfish and, if consumed by humans, can be fatal (Bushaw-Newton & Sellner, 1999). Pest populations such as rodents, flies and ticks are likely to proliferate with increased temperatures bringing with them disease and spoiling of food sources (Barata, 2017). Additionally, along with an increase of pests, there is likely to be more domestic and agricultural use of chemical pest control possibly resulting in increased adverse exposures and poisonings (Boxall et al., 2009; Barata et al., 2011). Pests are not only a nuisance and can exacerbate or cause mental health issues but, along with other animals such as ticks and snails, can also be vectors of disease such as hanta virus (vector: rodents), malaria (vector: Anopheles mosquito), dengue (vector: Aedes mosquito) and trypanosomiasis (vector: tsetse fly). Cockroaches, a common domestic pest can also exacerbate diseases such as asthma (Hamilton, 2005) and an increased pest population can increase the range and proliferation of urban pest-borne diseases such as leptospirosis, a disease endemic to South Africa and likely to be impacted by climate change (Lau et al., 2010; NICD, 2015; Barata, 2017). The prevalence of vector-borne diseases is likely to increase as the climate changes through greater vector proliferation, increased vector activity, faster reproductive rates and longer lifecycles, creation of vector habitats, faster pathogen growth rates, increased geographic range of vector activity as well as the introduction of new pathogens (Gubler et al., 2001; Chin & Welsby, 2004; Harrus & Baneth, 2005; Bloomfield et al., 2006; Eze et al., 2014). However, extreme weather events such as floods could potentially decrease vector-borne diseases through destruction of vector habitats (Gubler et al., 2001). Figure 4 below provides a summary of a few pathways, mechanisms and influencing factors that affect vector- and rodent-borne diseases within the context of a changing climate (Gubler et al., 2001) relevant for vector control in the WC.

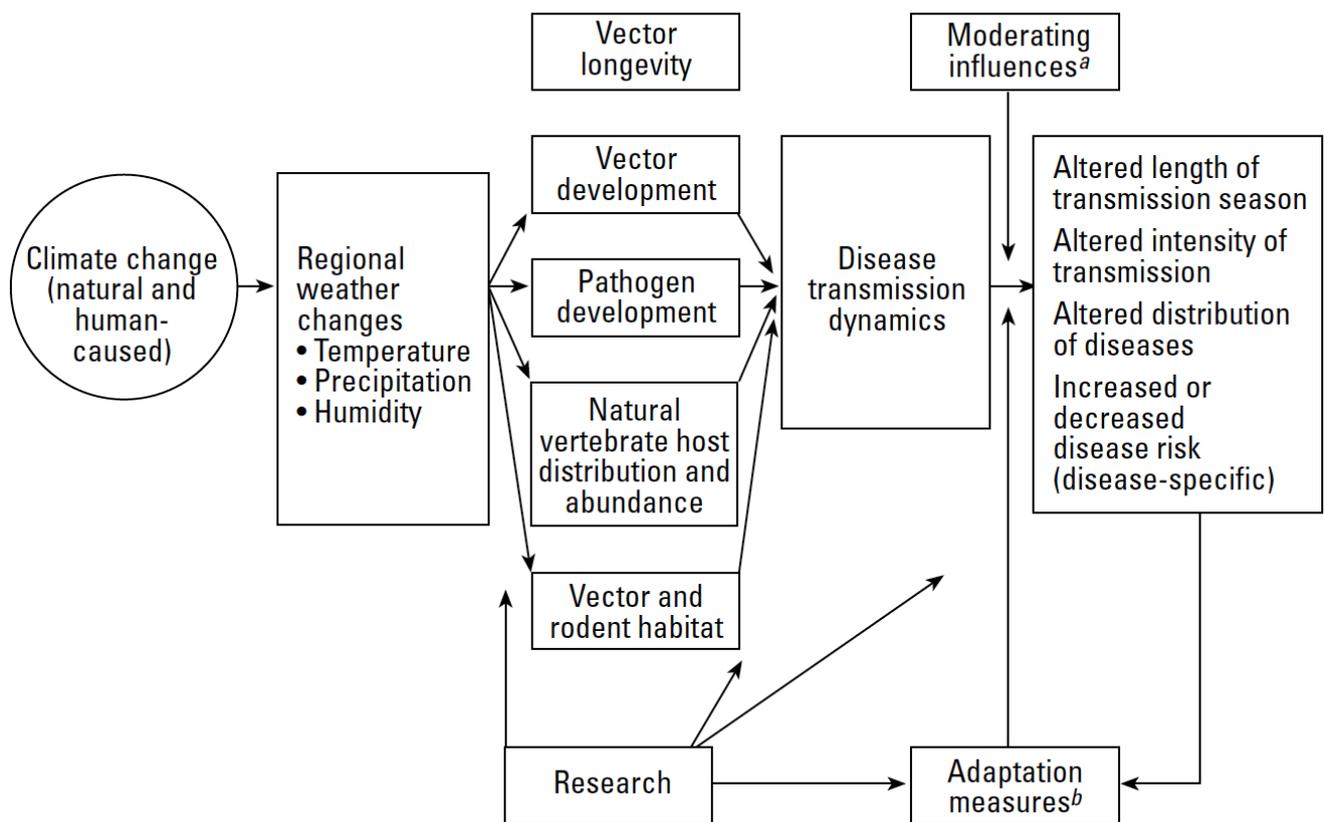


Figure 4: Various climate change-related pathways and factors for vector- and rodent-borne diseases (Gubler et al., 2001).^a Non-climatic factors. ^b Adaptive responses.

Land Use Change

Farmers in agricultural areas are vulnerable to changing weather patterns and often there is increased urbanisation as rural farmers look for more profitable opportunities in cities and towns. Due to urbanisation, environmental refugee migration and industrialization, regions often undergo rapid land use change particularly towards urban land cover. This change involves a greater surface of the ground covered with largely impermeable materials, such as concrete, that restrict the amount of water that seeps into groundwater and creates flood channels so that when it rains heavily, much of the storm water is channelled to densely populated areas and increases individual's vulnerability to flood-related disasters (Zhang et al., 2008). Increased urbanisation and associated land use change also leads to the development of urban heat islands whereby these densely built urban areas such as cities and informal settlements are hotter than surrounding, less dense, rural areas. This is due to less vegetation in these urban areas as well as the abundance of urban construction materials that trap heat, are highly reflective and have a high thermal mass, such as corrugated iron and concrete. It should also be noted that urban heat islands can provide an optimal environment for the breeding of vectors; a study conducted in Brazil found that the incidence of dengue was increased in urban heat islands compared to other urban areas (Araujo et al., 2015).

Corrugated iron is often the building material of choice for many low-income communities living in informal settlements in the WC and this increases individuals' vulnerability to heat-related health effects. A study conducted in informal settlements in Nairobi, Kenya found that an increase in child mortality and deaths due to non-communicable diseases (NCDs) coincided with an increase in temperature (Egondi et al., 2012). Scovronick and Armstrong (2012) explored housing type as a risk factor in heat-related deaths and stated that those living in informal houses were more vulnerable to heat-related mortality than those living in formal housing. As many of the WC's residents live in informal

settlements, the impacts of heat on the health of these individuals should be of concern to the province for climate change adaptation planning.

Social

Social risk factors also impact on health and can be categorized into environmental refugees, vulnerable groups, land use change and infrastructure and health services.

Displacement and Environmental Refugees

With a changing climate, the frequency and intensity of extreme weather events is projected to increase (Hales et al., 2003). The consequences for human health are not only from direct hazard-specific mortality and morbidity but might also result in social consequences such as displacement of communities and the creation of environmental refugees (Myers, 2002). As a result of these changes to the existing social structure, interpersonal violence or conflict over limited resources may increase (McMichael et al., 2012). Women and children are among those particularly vulnerable to increased violence such as domestic abuse, trafficking and sexual violence after extreme weather events (WHO, 2014). Following a disaster, a lack of privacy in makeshift shelters and sexual abuse are issues which adolescent girls particularly suffer (Bartlett, 2008). Based on this, the WCG should make provision for gender-sensitive preparedness to care particularly for the protection of women and children post-extreme weather events. Mental health issues, substance abuse and the increased spread of infectious diseases also arise out of severe social disruptions (McMichael et al., 2012).

Vulnerable Groups

There are several social groups in the WC that are more vulnerable to the adverse health impacts of climate change as listed in Figure 5. It is often the poorest in societies who are more likely to be impacted by climate change and yet the poorest have a reduced capacity to adapt. The poor are unable to invest in education, have limited resources to improve adaptive capacity, work in climate-sensitive sectors such as farming and fishing, have poor service facilities such as access to basic sanitation and safe drinking water and have less access to air conditioning (Hallegatte & Rozenberg, 2017). Outdoor labourers and those who are physically active in their occupation such as fire fighters, Expanded Public Works Programme employees, construction workers and emergency health workers are at increased risk of suffering heat-related deaths and illnesses and hazard-specific injuries such as burns and concussions (Schulte & Chun, 2009; Mathee et al., 2010). The potential loss or disruption of livelihoods has already been mentioned for occupations such as aquaculture and fisheries, agriculture and outdoor workers but individuals engaged in other occupational avenues could also be vulnerable. For example, tourism decreased in response to the recent drought in Cape Town, with those relying on the tourism sector for an income being the most affected (Roelf, 2018). Individuals with a compromised immune system such as those suffering from HIV/AIDS (Drimie and Gillespie, 2010), the chronically ill, both physically such as those with diabetes (Semenza et al., 1996) and mentally such as those suffering with depression (Clayton et al., 2017), possess less adaptive capacity to cope with climate change-related impacts to health and are therefore vulnerable. Individuals that have a poor health status might also be susceptible to acquiring new climate-related diseases or co-infections (Woodward, 1998; Cegielski & McMurray et al., 2004), may have a reduced physical capacity to be productive in their occupation (Mathee et al., 2010) or might be taking medications that place them at increased risk (Luber & McGeehin, 2008).

Infrastructure and Health Services

A lower standard of living due to climate-related urbanisation or environmental refugee displacement places excess strain on urban services such as the removal of refuse and the provision of water, sanitation and hygiene services (Costello et al., 2009). Indeed, increasing urbanisation in LMICs is an amplifier of NCDs where NCD-related mortalities are predicted to increase in South Africa and climate change may exacerbate this (Friel et al., 2011; Nojilana et al., 2016). A growing population, particularly

in urban areas of the WC, can result in further overcrowding and the development of inadequate housing which places strain on government service delivery and leads to poor hygiene and living conditions. These variables can exacerbate urban pest infestations affecting ecosystem stability and increasing the chances of chemical poisonings as mentioned above. Public health infrastructure is also vulnerable to climate change-related issues such as overcrowding and environmental refugees. Access to quality healthcare is not always an option for the socio-economically vulnerable and furthermore, public health services such as disease surveillance, health promotion, disaster preparedness and emergency service response needs to be cognizant of, and adaptable to, climate-related impacts. City infrastructure needs to be prepared for climate-related incidences that can lead to the destruction of roads and transport systems, negatively affect water quality and delivery and destroy the built environment, particularly poorly built houses.

Findings: Potential Western Cape Health Impacts

The WHO estimate that globally, climate change is projected to account for an additional 250 000 deaths annually between 2030 and 2050 (WHO, 2017). Although the risk factors identified play a key role in increasing the health impacts from climate change, there are several climate change-specific health impacts (Step 4 of Methodology) that may be directly or indirectly climate-related that the WCG should be considering in climate change adaptation strategies. Figure 5 provides a summary of the main health outcomes of projected climatic risk factors for the WC.

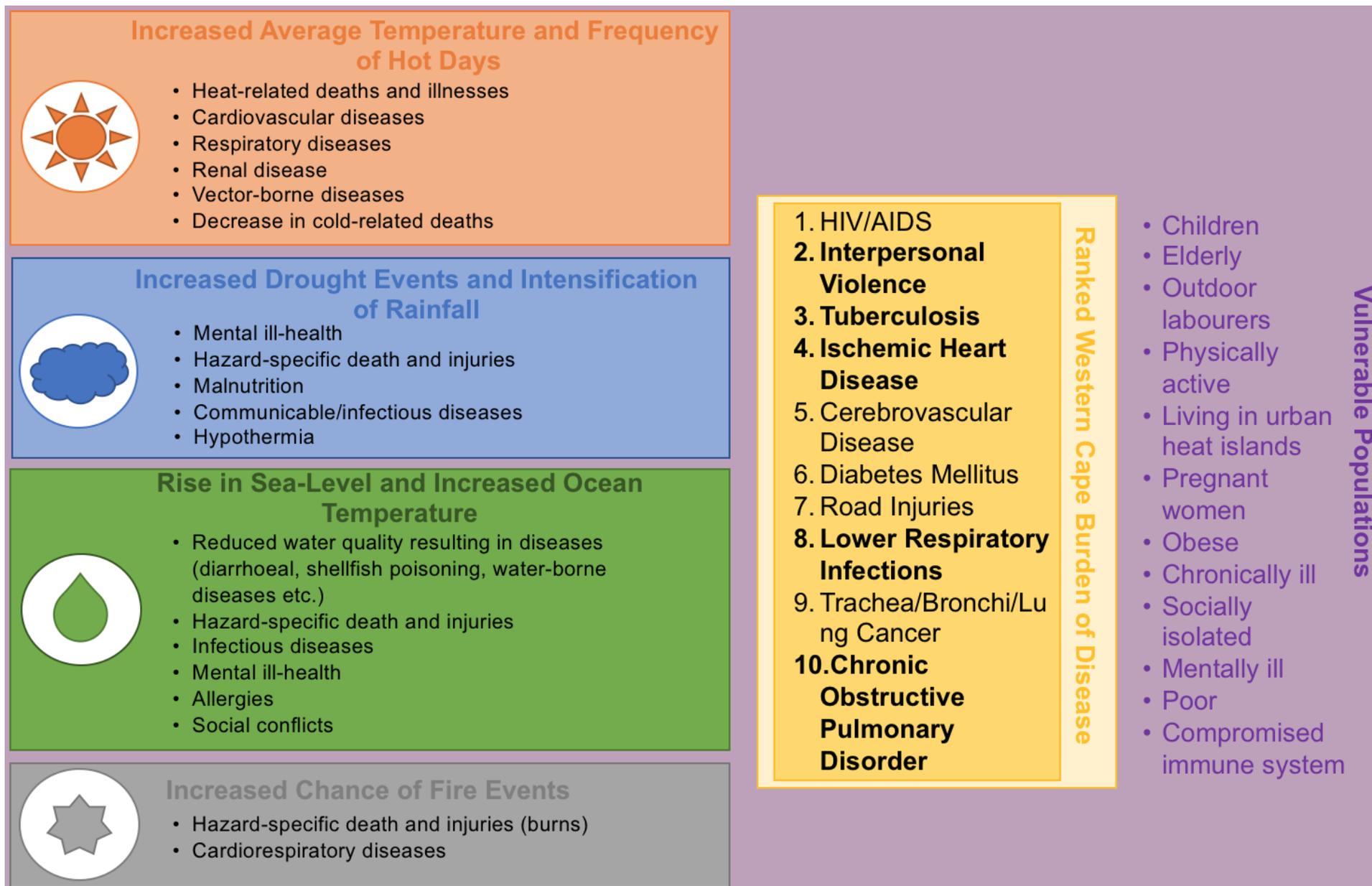


Figure 5: Summary of the main climate change-related health impacts based on the climate projections specific for the Western Cape, showing the province's burden of disease and vulnerable populations. Note that any diseases bolded in the burden of disease box are those mentioned in climate-specific boxes.

Direct Health Impacts

Hazard-Related Injury and Mortality

Climate change increases the frequency and risk of fires and, for the water-stressed WC, a combination of high temperatures, low humidity, low precipitation, strong winds and desiccated vegetation provides fuel for wildfires (Flannigan et al., 2009 & Flannigan et al., 2013; Blamey et al., 2014). Greater frequency and intensity of fires increases the demand for water when controlling fire outbreaks and places health risks such as hazard-specific injuries (burns and trauma) and cardiorespiratory diseases on firefighters and local residents (Stefanidou et al. 2008). Wildfires can also result in the release of persistent organic pollutants that are highly toxic such as dioxins. Dioxins are detrimental to human health and can result in cancer, immunological damage, reproductive and developmental complications (WHO, 2016). It is unclear in the literature the quantity of dioxins released from fynbos wildfires and furthermore, whether this is different to the quantity released from urban fires. This should be further explored within the context of adverse health implications from dioxin exposures.

Other hazard-specific injury such as concussions and drownings may also occur directly from extreme weather events. During the drought in Cape Town in 2017 and 2018, a number of residents were collecting and storing rain water in buckets as a water saving initiative. In an accident, a toddler drowned in a bucket of collected rain water (Charles, 2017). As a result of increasing temperatures and heatwaves, there is likely to be a further increase in the amount of heat-related deaths (heat stroke) and illnesses such as heat exhaustion/fatigue, heat syncope, heat cramps and dehydration (Review by Kovats & Hajat, 2008).

There is also an association between heatwaves, and days where temperatures were high, and motor vehicle accidents. Basagana et al. (2015) found a decrease in driving performance during high ambient temperatures and estimated a 7.7% (95% confidence interval [CI]: 1.2% to 14.6%) increased risk of accidents occurring in the study area of Catalonia in Spain. The authors noted that drivers were likely more distracted and fatigued on hotter days which resulted in reduced driving performance. Other researchers have found that, when analysing Finnish fatal road accidents, falling asleep while driving was more like to occur in warmer months than cooler months (Radun & Radun, 2006). Indeed, there is also a link between dehydration, that can occur at times of heat stress, and cognitive performance (Grandjean & Grandjean, 2007) which could also be a mechanism for increases in the number of motor vehicle accidents in hot weather.

Indirect Health Impacts

Non-Communicable Diseases

Although NCDs have been identified as a key issue for the 21st century, there has been limited focus on the link between NCDs and climate change globally, and particularly for the WC (Friel et al., 2011). This is despite several common NCD's being climate sensitive, such as asthma, bronchitis, respiratory infection, chronic obstructive pulmonary disease (COPD), type 2 diabetes, obesity, cancer (skin and lung), cerebrovascular disease and cardiovascular disease where, for example, the severity of symptoms is linked to increased temperatures (Colagiuri 2013). For urban populations of the WC, a particular concern is the worsening of the impact of the following NCDs: asthma, type-2 diabetes, cardiovascular disease, cancer, endocrine disruption from increased pesticide use and mental health and well-being. Asthma prevalence is predicted to increase from higher ground-level ozone concentrations, more places with allergenic vegetation and extended pollen seasons (Osborne et al., 2017; Alcock et al., 2017). Although mental health and climate change is discussed in other sections of this review, there is a likelihood of mental strain because of climate change amplifying NCDs and the impact on chronic physical disease, which needs to be taken into account (Padhy et al., 2015).

Increased average temperatures and number of hot days with an increased frequency of heat waves can also lead to mortality from cardiorespiratory diseases and exacerbation of renal diseases and

kidney stones (Tasian et al., 2014; Glaser et al., 2016; Watts et al., 2017). Scovronick et al. (2018) investigated the relationship between temperature and mortality (8.8 million recorded deaths) in South Africa over a 17-year period. Significantly more people died on very hot days (99th percentile) with a relative risk of all-cause, all-age mortality of 1.06 [1.03,1.09]. The elderly (> 65 years old) and young (< 5 years old) were found to be particularly vulnerable. Major causes of death were cardiovascular and respiratory diseases. Thus, within the context of climate change, the WCG health sector should be prepared for an increased burden of disease resulting from cardiorespiratory diseases, which already are a burden on the WC health system (Statistics South Africa, 2018).

An international study conducted by Buist et al. (2007) identified that individuals in Cape Town, compared to individuals in eleven other international cities, had the highest prevalence of COPD at Stage II or greater indicating the large burden of disease that COPD has on individuals living within the city. The association between air pollution, especially PM_{2.5}, an air pollutant sensitive to climate change, and COPD incidence is well established (Li et al., 2016; Tian et al., 2018). It is likely therefore that, with a changing climate and a continued high greenhouse gas emission scenario, the burden of COPD will worsen for the WC health sector.

Mental Ill-health

A neglected health research area on a provincial scale is the impact of climate change on mental health. Trauma, post-traumatic stress disorder, anxiety and depression after a catastrophic or life-threatening event will become more prevalent as climate change increases the frequency and severity of extreme weather events such as flooding and drought (Ahern et al., 2005; Berry et al., 2010). Severe and prolonged drought, floods and high temperatures can drive individuals, particularly farmers, into depression and even suicide (Maes et al., 1994; Page & Fragar, 2002; Ahern et al., 2005). Due to the recent drought and severe water restrictions placed on the agricultural sector in the WC, farmers suffered large financial losses with many seasonal farm workers losing their jobs and, along with increasing food prices, the poor suffer further (Phakathi, 2018). 2016 saw an increase in farmer suicides in drought-stricken regions of the Cape with insurance companies speculating the drought was responsible for the suicides (Child, 2017).

Regarding mental ill-health, climate change might also result in chronic distress (Brugha & Cragg, 1990; Coelho et al., 2004) and increased solastalgia, a distressing sense of loss due to environmental change (Higginbotham et al., 2006). Children are extremely vulnerable to early-life trauma that can affect subsequent emotional development (Perry et al., 1995). Often in poverty situations brought about by extreme weather events and climate change, children are left either unsupervised or in the care of non-primary caregivers, leading to physiological and psychological strain and possible collapse of social networks (UNICEF, 2011). Furthermore, absenteeism from school increases due to extreme weather events, climate change-induced poverty or other situational issues such as having to walk longer distances to collect water (UNICEF, 2011). Children, and women, can often become victims of interpersonal violence in times of disasters, which is not only traumatic, but might also increase the spread of sexually transmitted diseases (Myers et al., 2011).

Violence

Quantitative analysis of the influence of climate on the risk of human conflict, including *inter alia* interpersonal violence, intergroup violence and crime, has recently become a research area of interest within the climate change and health literature. Hsiang et al. (2013) found that the risk of human conflict increases as precipitation and temperatures deviate from normal ranges. Intergroup riots in India seem to increase with rainfall loss (Bohlken & Sergenti, 2010) and political and intergroup violence in East Africa and Kenya increased as temperatures rose, although political factors are often large contributors to violence (O’Laughlin et al., 2012; Theisen, 2012). Associations with altered precipitation levels and violent conflict have also been noted in the literature, most notably with collective violence rather than

interpersonal violence, usually through the mechanism of economic shocks and subsequent poverty (IPCC, 2014). However, although links have been established between collective violence and climate variability, most authors agree that the political landscape has greater influence on collective violent conflict than climate change (IPCC, 2014).

Mares and Moffett (2016) have estimated that globally, a one-degree Celsius rise in temperature could account for a 5.92% increase in homicide rates, whereas in Africa a similar rise is equated with a 17.94% increase. The authors suggested that street violence and economic inequality were contributing factors to the high homicide rates projected for Africa. In the USA, violent personal crime such as murders, rapes, assaults, robberies, burglaries and larceny are projected to increase with climate change (Ranson, 2014).

The physiological mechanisms linking increased interpersonal violence and crime to climatic variables such as temperature have not been determined, although various psychological theories of the temperature-aggression relationship are reviewed by Anderson (1989). Links have been established globally between temperature and aggression (Anderson, 1989), domestic violence (Auliciems and DiBartolo, 1995), homicides (Mares and Moffett, 2016), assault and rape (Ranson, 2014). Breetzke's extensive work on temporal analysis of crime in South Africa has revealed that property crime and violent assault rates are highest during summer, particularly in the month of December (Breetzke and Cohn, 2012; Breetzke, 2015). Although the temperature/aggression theory was acknowledged, a link between temperature and criminal activity was also explored through Routine Activity Theory, whereby many people are outdoors or away from their homes in December due to the pleasant weather and are therefore more vulnerable to being victims of criminal acts.

A theoretical study by Rabie (2008) suggests that there is a link between xenophobia, climate change, and migration in South Africa, hypothesizing that scarcity of resources exacerbated by climate change will have the potential to increase the likelihood of violent conflicts against migrant groups. Swain et al. (2011) also predicts that climate change adaptation abilities of various African countries will be greatly reduced by violent conflict and will therefore "result in a serious humanitarian crisis in the southern African region".

Water-borne Diseases

Water-borne diseases are also highly susceptible to increases in temperature (El-Fadel et al., 2012) and also surge in times of drought due to poor sanitation and hygiene practices as well as reduced water quality (Cann et al., 2013). Relationships have been established between increased temperature and/or extreme weather events such as flooding, heavy rainfall, drought, ENSO and hurricanes, and hepatitis, rotavirus, norovirus, enterovirus, cholera, giardia, typhoid and legionnaires disease* (Karagiannis et al., 2009; Wang et al., 2012; Review by Cann et al., 2013). As the WC is a coastal province it is important to mention that an increase in harmful algal blooms and increased ocean temperature have been correlated with outbreaks of cholera as the bacteria is transmitted to humans through the consumption of raw shellfish (Epstein et al., 1994; Colwell, 1996). In Cape Town, during the summer months diarrhoea cases usually surge in the summer months, particularly for children under five years old, and, in response to the recent drought, lowered hygiene standards as a result of water saving might have been responsible for the increased number of diarrhoea cases in January 2018 and possibly the increased incidence of typhoid in the region (Evans, 2018). There is also the concern of increased antibiotic resistance during droughts as residents acquire more bacterial and viral infections through decreased sanitation and improper use of medications (Green, 2018). Furthermore, water-borne diseases and diarrhoea often result in severe dehydration of individuals, especially

* This specific concern did not arise from the reference documents, but rather was identified when searching through the literature

children, which not only is a severe health outcome on its own that can be fatal (Whitehead et al., 1996), but can also make individuals susceptible to heat-related illnesses. In 2016 there were news reports of an elderly man who died after his wound was infected with the water-borne bacteria, *vibrio vulnificus* when swimming in Kaaimans estuary in Wilderness (Stander, 2016). Research conducted in the Eastern Cape found that *vibrio vulnificus* can survive wastewater treatment and is a health concern to rural communities (Igbinsosa et al., 2009). Currently, the CSIR has been requested to conduct a research project on the long-term effects of poor water quality within the context of a changing climate and subsequent health implications, however, our team did not find any research outcomes from this study yet. Globally, researchers have found increased incidence of the bacteria with warmer water temperatures as a result of global climate change (Paz et al., 2007; Martinez-Urtaza et al., 2010) and therefore should be a concern to the province. Figure 6 below provides a conceptual framework of how low water quantity and quality can directly and indirectly affect adequate sanitation, hygiene and food and nutrition insecurity.

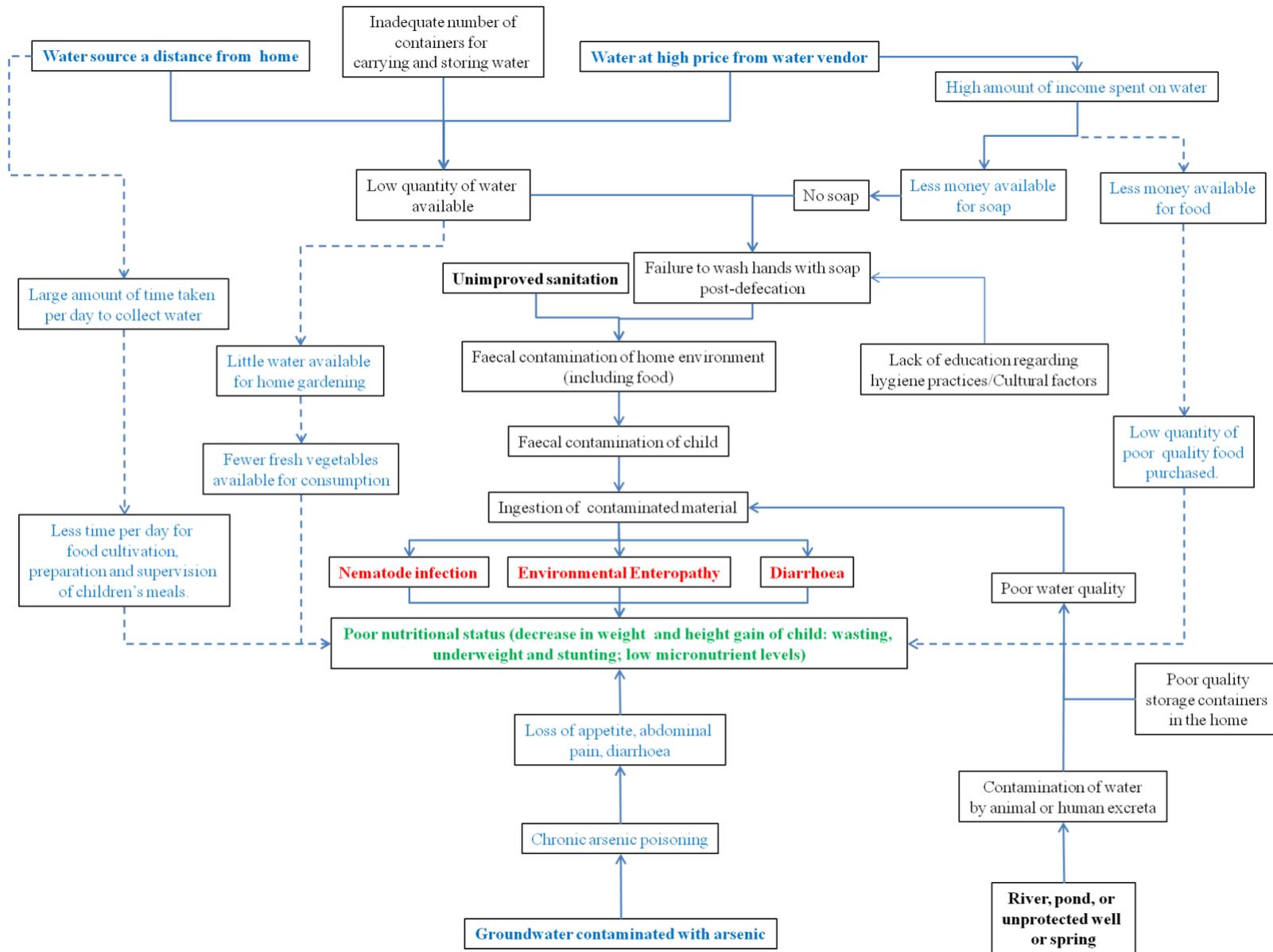


Figure 6: Direct and indirect effects of poor water quality and quantity on child health (Dangour et al., 2013).

Vector- and Pest-borne Diseases

A changing climate will also affect vectors that carry and transmit diseases. Changes in temperature, precipitation and humidity provide optimal breeding conditions and as such disease carrying vectors are likely to proliferate at higher rates as detailed above (Figure 4). As regions warm, previous areas that were uninhabitable to vectors might become habitable such as highland areas that were too cold for mosquitoes, might become more thermally optimal, as is the case with the Ethiopian highlands (Siraj et al., 2014). It is not only the vectors that will be affected by climate change, but the parasites and pathogens might also replicate and mature faster at higher temperatures thus exacerbating the burden of vector-borne diseases (Gubler et al., 2001). Modelling of mosquito geographical ranges have shown, that the WC might become “marginally suitable” by 2070 for sustaining the *Aedes aegypti* mosquito under a future emissions scenario of an increasing global population with slower economic and technological growth (A2) (Khormi & Kumar, 2014). Others suggest that under a future emissions scenario of a balanced fuel source with rapid economic growth (A1B), the *Aedes aegypti* mosquito is likely to retain a similar geographical area as present-day conditions (Campbell et al., 2015). The *Aedes aegypti* mosquito has the capacity to transmit diseases such as Dengue and Zika and these mosquito-borne diseases should be considered in long-term strategic health planning by the WCG. Therefore, although vector-borne disease, such as malaria, are currently contained in the north eastern parts of South Africa, it is possible that, in future throughout South Africa due to a changing climate, there could be an increase in mosquito-borne diseases such as West Nile virus (Reisen et al., 2006; NICD, 2014), dengue (Araujo et al., 2015; NICD, 2015), malaria (van Jaarsveld & Chown, 2001; Tanser et al., 2003), Rift Valley fever (Linthicum et al., 1999; NICD, 2010); tick-borne diseases such as tick-bite fever with associated complications such as encephalitis (Freaan et al., 2008) and Crimean-Congo haemorrhagic fever* (NICD, 2017); rodent-borne diseases such as hantavirus (Fang et al., 2010; Ithete et al., 2014); other vector-borne diseases such as plague (Ben Ari et al., 2008), schistosomiasis (van Jaarsveld & Chown, 2001; NICD, 2009) and leptospirosis* (Lau et al., 2010; NICD, 2015).

It should also be considered that due to global trade and travel, outbreaks of vector-borne diseases in other countries might still have impact for South Africa. For example, during the outbreak of plague in Madagascar in 2017, the World Health Organization identified South Africa as a priority country for readiness and preparedness to deal with a potential plague outbreak (WHO, 2017). Likewise, a case of East African trypanosomiasis, transmitted through the bite of a tsetse fly, was treated in Pretoria (NICD, 2014) and as climate change is anticipated to affect the range the parasitic protozoa *Trypanosoma brucei rhodesiense* transmitted by the tsetse fly (Moore et al., 2011), African trypanosomiasis could be problematic for the people of the WC in the future (Figure 7).

* This specific concern did not arise from the reference documents, but rather was identified when searching through the literature

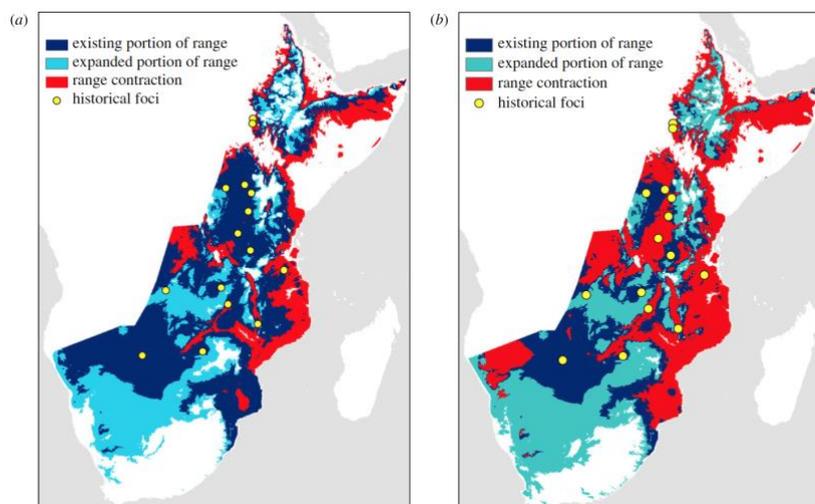


Figure 6: Existing and projected range of the parasitic protozoa *Trypanosoma brucei rhodesiense* as an indication of African trypanosomiasis in 2055 (a) and 2090 (b) under a high emission, high population scenario with little technological advancement (Moore et al., 2011).

As mentioned above, with many environmental and societal risk factors, there is likely to be an exacerbation of pest infestations in low socio-economic communities (Barata et al., 2011). Higher temperatures result in higher reproduction of pests, with pests moving into areas previously not inhabited and turning non-pests into new pests (Barata et al., 2011). Additionally, within the agricultural sector, there is likely to be a proliferation of pests on crops as a result of climatic risk factors (Rosenzweig et al., 2001). Ultimately an increase in pests will result in an increased need for effective pest control with individuals often resorting to chemical methods. Zinyemba (2017) conducted a case study on small scale cotton farmers in Zimbabwe with regards to their pesticide usage in relation to a changing climate and subsequent pest populations. It was found that climate change was a key factor to increased pesticide exposure in these farmers. It should also be noted that the acting effects of certain pesticides might also change in response to a changing climate such that chemical compounds could become more hazardous or a higher quantity of chemicals might be required (Patterson et al., 2004; Boxall et al., 2009). Therefore, there is likely to be increased exposure to hazardous chemicals and pesticides with subsequent poison-related incidences with a changing climate. Often the chemicals used in poor urban areas for pest control are illegal street pesticides that are too toxic for domestic use and as such, the likelihood of a poison-related accident or death increases in these areas (Rother, 2010). Additionally, in times of flooding there is increased run-off, and with an increased use of chemical pest control, there may be a subsequent elevation in chemical pollutants in flood waters (Patz et al., 2008).

Communicable Diseases

Living in conditions with low sanitation and hygiene, increased global travel and trade and a changing climate are all risk factors for the spread of communicable or infectious diseases. Globally, climate change is likely to increase the spread of tuberculosis (TB) (Onozuka & Hagihara, 2015) (discussed in greater detail below), meningitis (Dukic et al., 2012), influenza (Towers et al., 2013), measles (Omonijo et al., 2012), pneumonia* (Xu et al., 2014) and hand, foot and mouth disease* (Phung et al., 2018). The recent study conducted by Phung et al. (2018) in Vietnam calculated that for every 1 °C rise in monthly temperature above 26 °C, hand, foot and mouth disease increased by 7% (relative risk of 1.07; CI: 1.05-1.09). As the disease can occur throughout South Africa (NICD, 2016), this could become an emerging issue for the WCG. Regarding infectious diseases, Thompson et al. (2012), when investigating how climate change affects children's health in Limpopo, warned that by 2050, with

* This specific concern did not arise from the reference documents, but rather was identified when searching through the literature

current projections of increasing temperatures and decreasing rainfall, respiratory infection and diarrhoea could reach epidemic proportions in children if child-specific adaptation strategies are not adopted as a matter of urgency.

Food-borne Diseases

Most of the urban poor who live in townships and those living in poor rural areas cannot afford refrigeration in their homes and, with temperatures projected to increase along with increasing water scarcity, food-borne diseases such as salmonellosis, campylobacteriosis and listeriosis are becoming increasingly common. In the UK, Lake (2017) has identified campylobacteriosis incidence peaks in warmer temperatures and, as the disease is prevalent in Cape Town (Lastovica et al., 1986), it should be considered within the context of climate change in the province. Recently, there have been reports of increased incidence of the food-borne disease, listeriosis with the most vulnerable populations being those whose immune systems are compromised, the elderly, infants and pregnant women (Pava-Ripoll et al., 2012). Generally, changing climatic conditions such as increased temperature and altered rainfall can result in increased pathogen environmental survival, proliferation and development as well as increased prevalence within the host (Greer et al., 2008). Pava-Ripoll (2012) conducted the first study, in the USA, which identified flies (*Lucilia sericata* and *Lucilia cuprina* from the family Calliphoridae) as vectors for *L. monocytogenes* (the bacteria causing listeriosis). *Lucilia sericata* and *Lucilia cuprina* are prevalent throughout the WC and their distribution patterns appear to be affected by rainfall, humidity and maximum temperature (Williams et al., 2014). The *L. monocytogenes* can withstand temperatures ranges of 0 °C to 45 °C and there have been conflicting results in research studies of seasonal impacts on *L. monocytogenes*. Globally, more research is being called for on Listeria transmission in relation to climate change as the influence of seasonality is unclear (Semenza et al., 2012).

Food and Nutrition Insecurity-related Diseases

The IPCC (2014) identifies food security as a key risk for urban populations due to climate change and states with high confidence that climatic drivers will exacerbate food insecurity, felt particularly by the urban poor, through spikes in food prices and food-price shocks. Adverse health outcomes of food insecurity include malnutrition (Grace et al., 2012), stunting (Jankowska et al., 2012) and anaemia (Denton, 2010). Health outcomes of malnutrition includes both stunting due to climate change-related food insecurity but also nutrient deficiencies due to nutrition insecurity as discussed above, whereby individuals do not receive adequate nutrition (fruits and vegetables) or diet diversity (Dangour et al., 2015). In this way, climate change-induced food and nutrition insecurity is likely to affect the poor, but also the wealthy, through reduced availability of nutritious fresh foods.

Reproductive Health

Climate change, specifically increased temperature, will also impact on reproductive health such that there is an increased risk of preterm births (Basu et al., 2010) and an increased incidence of urinary tract infections* (Liu et al., 2017). Indeed, with mental ill-health associated with suffering and surviving extreme weather events, reproductive health is also negatively impacted. Although not a climate-related disaster, the psychological trauma suffered by pregnant women and their foetuses during the attack on the World Trade Centre in 2001, which created a large scale environmental disaster for New York City, was highly correlated with longer gestation and decrements to the infant's head circumference (Engel et al., 2005). This study provides evidence that psychological trauma can result in adverse birth outcomes.

As discussed above, there are a plethora of adverse health outcomes as a result of climate change with some being directly or indirectly related to climate change. Figure 5 above provides a summary of

* This specific concern did not arise from the reference documents, but rather was identified when searching through the literature

the health outcomes associated with climatic changes projected for the WC (Step 6 of Methodology) and highlights those diseases which are currently ranked on the Top 10 WC burden of disease list that are likely to be exacerbated by a changing climate. Vulnerable populations are mentioned and are likely to be most affected by all of the climatic variables.

Findings: Interventions

The findings from this literature review of climate change risks and impacts on the health sector in the WCG was used as the basis for the extensive literature review of WC climate change and health interventions. The research approach contained five investigative stages, developed by the UCT research team. Figure 8 below provides a summary of the findings of the search on adaptation and mitigation strategies and interventions.

Methods	Key Points and Recommendations
Western Cape climate change database review	<ul style="list-style-type: none"> • WCG has a non-exhaustive climate change database of public and private climate change projects. • There is significant potential to build health additions into existing WC climate change interventions. • WCG should create a mechanism to capture climate change-related projects at inception thereby strengthening public-private communication and improving the potential for health to be included at early project stages.
Western Cape key climate change documents review	<ul style="list-style-type: none"> • Health-specific sections need to be added to key WCG climate change documents to create a “health and climate change in all policies” approach. • Efforts of improving research translation should be made by researchers and WCG such as by creating a platform to upload recent research articles and findings.
Search for Western Cape climate change interventions	<ul style="list-style-type: none"> • Additional adaptation and mitigation interventions in the WC (not listed in the database) were primarily policy level strategies and frameworks. • The policies should go a step further to make allowance for, and incorporate, mechanisms that will lead to practical solutions and projects that will have a sustainable impact on the livelihoods and wellbeing of community’s’ health impacted by climate change.
Search for national climate change interventions	<ul style="list-style-type: none"> • National and provincial government departments should encourage and support the creation of practical health-specific climate change interventions (e.g. DOH’s ‘one-stop-shop’ health and climate change website as proposed in the National Climate Change and Health Adaptation Plan 2014-2019 but has not yet been created). • A climate change health-specific flagship should be created, and further research should be done on identifying potential indicators for evaluation and monitoring purposes.
Search for global climate-health projects	<ul style="list-style-type: none"> • Successful global adaptation and mitigation strategies can be contextualized to South Africa and utilized to address projected adverse health outcomes from climate change. • WCG should create a database that summarizes successful global climate change projects for national and provincial access for consultation at initial adaptation and mitigation project stages.

Figure 7: Process summary identifying climate change and health adaptation and mitigation strategies.

The five stages of research are outlined below.

Stage 1: Analysis of the Western Cape Climate Change Database

Introduction: The WC climate change database is a compilation of public and private sector projects that range in size and initiative, but altogether aim to combat climate change in one of two ways; reducing greenhouse gas emissions (mitigation strategies) or adapting to specific climate-related hazards (adaptation strategies) ([WCG, 2018](#)). The WCG acknowledges that the database is not exhaustive and is updated on a quarterly basis, as new information arises and as projects are completed. For inclusion to the database, a climate change project template must be submitted for review to the database administrator. The database was last updated on January 30, 2018.

Methods: A review of the WC climate change database (189 projects) was completed from October to December 2017. The analysis was done to understand how many interventions in the WC database take health into consideration when addressing climate change. Each intervention's aims and objectives were examined to see if health was included as a priority in the projects mitigation or adaptation strategy. For the purpose of this analysis, the projects were allocated into 'health-related' projects or 'non-health-related' projects. A 'non-health-related' project was classified as having no explicit or obviously foreseeable impact on human health outcomes, whereas a 'health-related' project had a discernible impact on human health. The health-related projects were further divided into direct or indirect impact on health based off the projects aims, objectives or description. A project with a direct impact on health explicitly incorporated health outcomes as an aim or objective that the project intended to address, whereas a project with an indirect impact on health, although not explicitly stated in its aims, displayed a foreseeable effect on health and was perceived as an unintended co-benefit. Finally, direct and indirect projects were further categorized as either 'ongoing' or 'complete'. This was done to highlight the interventions that still have the opportunity to incorporate health-related goals to strengthen provincial preparedness for climate change-related health outcomes (Appendix 6).

Findings: Of the 189 climate change projects, 152 were non-health related and 37 were health related. Nine of the 37 climate change health-related projects directly impact on health with six ongoing projects and three completed projects (Appendix 7). There were 28 of the 37 climate change health-related projects that indirectly impact on health with 21 ongoing projects and seven completed projects (Appendix 7). Due to time and funding limitations, not all of the projects can be analysed, however, an example of a project that directly impacts on health is the *Mamre Ceilings Pilot Project* which aims to combat adverse health outcomes caused by damp and mould as a result of poor thermal efficiency and insulation in homes ([Mamre Ceilings Project, 2014](#)). An example of a project that indirectly impacts on health is the *WC Green Economy Strategy Framework* where various clean energy alternatives (such as bicycles) are discussed in mitigating CO₂ emissions. Although health improvement was not mentioned as an aim or objective, the strategy acknowledges the co-benefits of clean energy alternatives like bicycles in improving employee productivity and health ([Green is Smart, 2013](#)).

Recommendations: Although the *Mamre Ceilings Pilot Project* overseen by the City of Cape Town, is considered to directly impact on health, additions could be made to the project (and several other direct and indirect health-related projects in the WC climate change database) to address climate change-specific health outcomes through simple additions and / or modifications. Since the project involves visiting 230 homes, a simple climate change adaptation strategy could be the creation and distribution of an educational pamphlet for recipient homes about climate change-related adverse respiratory conditions and risk factors. This is an example of including "health and climate change in all policies". Regarding the *WC Green Economy Strategy Framework*, cycling, as a benefit in reducing non-communicable diseases, could be further explored. The United Kingdom have created the *Cycle to Work* scheme which provides individuals with tax exemptions and bicycle loans to encourage cycling

as a form of commuting to reduce air pollution and improve health (UK Government, 2011). A similar initiative could be explored under the *WC Green Economy Strategy Framework*. Many of the projects in the database had no government involvement and no relationship with the WCG was pursued by the project leaders. It appears that limited effort was made to inform government of these projects prior to implementation. We strongly recommend that the good effort of the WCG to have a database capturing all implementation projects be strengthened, and there be a mechanism put in place prior to implementation whereby project leaders can inform the WCG of their upcoming projects. This is an opportunity for government and private sector partnerships to be strengthened. More effort should be made to advertise the database amongst academics, researchers, private sector, other government departments etc. and when a project is added to the database, the WCG should be alerted. This will then allow the WCG the opportunity to review projects and encourage projects to include a health component at the onset. Multi-solving for climate change and health is not only cost-effective, but also beneficial to safeguarding the health of current and future generations to come (Sawin et al., 2018).

Stage 2: Western Cape's Key Climate Change Documents and Health

Introduction: The WCG have eight key climate change documents of which one focuses specifically on health with the rest focusing mainly on non-health topics such as; human and natural systems such as eco-systems and biodiversity, natural resources, renewable energy, coastal and marine systems, agriculture, the tourism sector, economic resources and infrastructure, and the built environment. The documents (Appendix 8) were predominately developed off one another and have dual perspectives on climate change response strategies: climate change adaptation recognises the effects of climate change and the “need to adapt behaviour to these changed conditions”; and climate change mitigation that focuses on “the reduction of the intensity of climate change effects by reducing greenhouse gas emissions” (DEA&DP, 2008).

Methods: The eight key WCG climate change documents were examined in this section to assess if health was included as a WCG climate change focus topic.

Findings: The majority of the documents examined appear to repeat the same sentiment of health and climate change making the general link that climate-related hazards will have an impact on human health but do not provide any further analysis or health-specific policy recommendations. The mention of health is often vague and makes little reference to relevant research studies most likely because government departments do not have access to the latest research. Furthermore, useful and relevant adaptation strategies to targeted at addressing projected health outcomes of climate change are often missing and this could be because relevant officials and government departments are unaware of the potential impacts. The Climate Adaptation Plan of Action (CAPA) from 2011 was a report generated on the “development and process of the city’s health-sector based climate adaptation plan of action” and was the most comprehensive document in terms of adaptation planning for addressing projected hazards and impacts on human health in the City of Cape Town (CAPA, 2011).

Recommendations: After completing a review on prominent WCG climate change documents, we recommend that key climate change documents of the WCG include more prominent health components explaining the integration of health into the topics to support the approach of “health and climate change in all policies”. We also recommend that the WCCCRS (2014) be updated to include measurable indicators. For example, the updated WCCCRS should incorporate health indicators that could be subject to surveillance, monitoring and evaluation. The [Lancet Countdown](#) provides an excellent example of indicators that can be tracked to monitor climate change influences on public health. Many of the documents call for further research in better understanding the association between climate change and health. Building climate change and health into existing policies and plans will be the simplest and most effective response strategy that the WCG can be doing (DEA&DP, 2016). A

formal process for encouraging research translation of academics' findings on climate change and health, which are particularly relevant for the WCG, need to be urgently put in place. For example, we recommend the WCG establish a platform whereby researchers can submit their current research findings and publications, and these would then be internally circulated with government officials notified when a new research project has been uploaded.

Stage 3: Search for Western Cape Climate Change Interventions or Projects

Introduction: The WC climate change database is not exhaustive; therefore, a further search was completed to find any additional climate change adaptation and mitigation interventions or projects in the WC.

Method: The first nine pages of a Google search on climate change interventions in the WC was cross-checked against the existing WC climate change database. The search terms used were: "Western Cape" AND "climate change" AND "adaptation interventions" OR "mitigation interventions". Removing the word "intervention" from the search terms did not highlight any additional findings.

Findings: There were 24 additional adaptation and mitigation interventions, or projects, found that were not included in the WC climate change database (Appendix 9). The majority (n = 18) were policies, frameworks, strategies, plans or report-related (e.g. Towards Day-to-Day Resilience: A Policy Framework for Climate Change Response in the West Coast District, A Comparison Report of Institutional Pathways for Municipalities, Developing a Municipal Adaptation Plan (MAP) for Climate Change: The City of Cape Town). The remainder (n = 6) of the documents were made up of case-studies, a website and workshops which the WCG did not deem to be projects and therefore were not included in the WC climate change database. It appears that one of the weaknesses of some of the documents found in the search were that they were not "climate change adaptation strategies" as they did not utilize climate change projections in their recommendations.

Recommendations: There is considerable and strong policy and frameworks in place in addressing climate change and health in the WC, but fewer tangible or practical interventions or projects that translate to on-the-ground, actionable projects. The policies found in the search are important and needed, but the documents need to go a step further to make allowance for, and incorporate, mechanisms that will lead to practical solutions and projects that will have a sustainable impact on the livelihoods and wellbeing of community's' health impacted by climate change. For example, funding mechanisms for climate change and health should be made available at a strategic level.

Stage 4: Search for National Climate Change Interventions or Projects

Introduction: A search on national climate change interventions was conducted to see what responses, strategies and action plans are currently in place to address climate change-related health outcomes. This search was conducted to determine South Africa's climate change and health response and to identify whether the WCG could incorporate some national strategies on a local level.

Methods: The following search terms were placed into Google: "Republic of South Africa" AND "action plan" OR "intervention" OR "strategy" AND predicted health impact (Figure 5). "Climate change" was not specified in the search terminology because we did not want to limit the scope of the results and rather aimed to find existing interventions that are in place for the specified health outcomes (regardless of whether they are related to climate change or not).

Findings: The national literature search also predominantly produced a variety of policies, strategies, recommendations and frameworks (Appendix 10 lists a few examples) that are based around future

commitments to address climate change-related health outcomes, for example, the National Climate Change and Health Adaptation Plan (2014-2019). Some tasks mentioned in national strategies have not yet been actioned such as the Department of Health's "one-stop-shop" website on climate change-related health implications. This is a strong indication of the governments recognition of the need to highlight health as a priority area within the climate change domain. This is a commendable idea that urgently needs to be put in place.

Recommendations: It is recommended that all national and provincial government departments encourage and support (e.g. provision of capacity) the Department of Health in making the one-stop-shop website come to fruition. For example, a monitoring indicator for a "one-stop-shop" website could be the number of visitors the website receives annually. In the National Climate Change Response Monitoring and Evaluation System Framework (2016/17) there is recognition that a flagship programme for health and climate change is non-existent. It is recommended that a climate change health-specific flagship is created, and that further research is done on identifying potential indicators for evaluation and monitoring purposes of climate change-related health outcomes and impacts on the population (e.g. drawing on the [Lancet Countdown](#) indicators).

Stage 5: Search for Global Climate Change Interventions or Projects

Introduction: As a final stage, global climate change interventions were evaluated to identify what methods are currently underway in addressing the projected health impacts of climate change. This is useful to the WCG to take example from what has been successful globally in combatting climate change-related health outcomes.

Methods: A Google search was completed using the following search terms: "global interventions for combating climate change", "worldwide solutions to climate change related issues", "global climate change interventions for [specific projected health outcomes listed in Figure 5]".

Findings: For some health outcomes (e.g. respiratory diseases, malnutrition, infectious diseases), adequate examples of climate change adaptation intervention strategies (i.e. those strategies which consider a changing climate inherent in their design, rather than as a co-benefit) were not found. This signifies that climate change and health strategic planning is in its early phases and much work is needed in this sector. Appendix 11 however, details at least one global project that addresses the other WC-specific health outcomes (e.g. heat-related illnesses, cardiovascular and renal diseases, mental ill-health, allergies, social conflicts, hazard-specific deaths and injuries, water quality-related diseases, vector-borne diseases). Global examples of programmes addressing environmental health risk factors with resilience co-benefits are thus listed in Appendix 12 and could be considered by the WCG to address health issues.

Recommendations: The global adaptation arena for climate change and health interventions is progressive and rapidly evolving. Many of the initiatives found in our search have begun to not only acknowledge the co-benefits of a dual approach of climate change and health, but also the economic savings, the strength of multiple constituency engagement, and the short- and long-term benefits of safeguarding the environment and population health (Sawin et al., 2018). In light of this, it is recommended that the WCG begins to use global success stories from interventions that elicit co-benefits. Successful adaptation and mitigation strategies at a global level (Appendix 11) should be utilized as examples in the creation and implementation of climate and health interventions in the WC, as well as in the broader South African context. For example, when the WCG are reviewing strategies and action plans for climate adaptation and mitigation projects, these global interventions should be reviewed for ideas. It is recommended that these global projects (Appendix 11) be reviewed regularly and be summarized into a database whereby national and provincial government officials can easily

access these. Furthermore, specific strategies designed to address future projections of a changing climate are needed for the health outcomes where adaptation strategies are not known globally.

Findings: Research Gaps in the Western Cape’s Climate Change Response Strategy (2014)

A health-focussed knowledge gap analysis was conducted to determine the gaps and areas for development in the WCCCRS (2014). It was necessary to send out a questionnaire to compliment the literature review gap analysis to determine if any climate change and health researchers in the WC were working on topics that had not yet been published, or were conducted as student theses for example, and would be found mostly on university websites, if not yet published. Of the researchers that received the questionnaire (N = 292), 58 consented to taking part with 31 researchers identifying themselves as having conducted or planning to conduct research on climate change and health in the province.

Researchers participated in the questionnaire from a variety of institutions in the province such as the University of Cape Town, The Council for Scientific and Industrial Research, WCG (Department of Environmental Affairs and Development Planning), Lentegeur Psychiatric Hospital and non-governmental organisations. Just over half of the respondents were male (53.4 %) and 32.7 % of the total respondents had the title of Professor or Doctor.

Results of the Research Questionnaire

Climate Change and Health Researchers

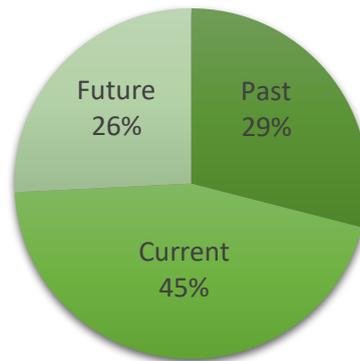


Figure 8: Percentage of respondents conducting research on climate change and health in the Western Cape (N = 31).

Respondents were able to select whether they have in the past, are currently, or plan to in the future, research climate change and health topics in the WC. Most respondents (45%) were currently conducting climate change and health research on the WC (Figure 9). Although 26% of respondents had never researched the topic, they indicated planning to conduct WC-specific research in the future which illustrates a growing interest in conducting province-focused research.

Previous and Current Research Topics

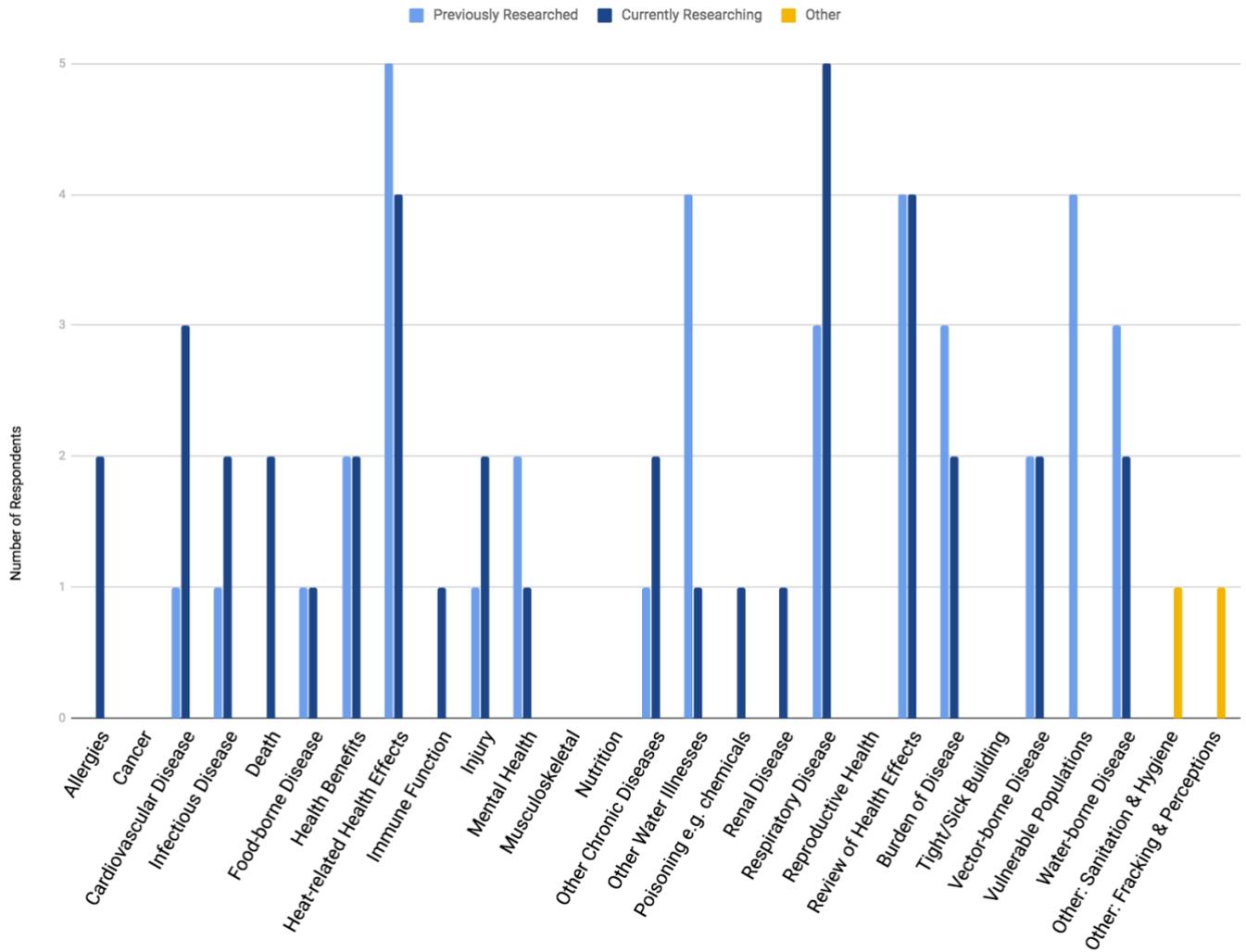


Figure 9: Respondents currently or previously researching climate change and health-related topics in the Western Cape (N = 31).

Topics that were commonly researched in the past include: heat-related health impacts, water-borne diseases, respiratory diseases, the burden of disease, vulnerable populations and a review of all health impacts. Current topics of high interest include: respiratory and cardiovascular diseases, heat-related health impacts and a review of all health impacts. However, no respondents indicated conducting research on cancer, musculoskeletal injuries, nutrition, reproductive health or tight/sick building syndrome.

Future Research Areas

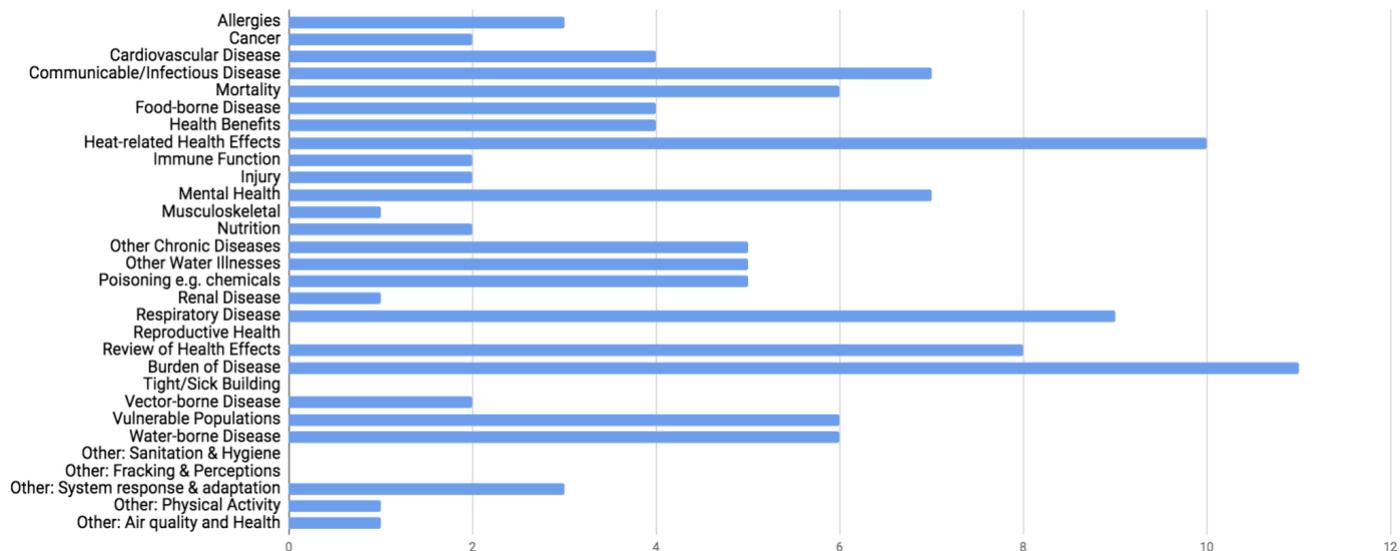


Figure 10: Topics that researchers identified as areas of future research in the Western Cape (N = 31).

When asked what areas researchers would like to focus on in the future, common responses that were chosen from a check box were:

- Infectious diseases (n = 7)
- Mortality (n = 6)
- Heat-related health effects (n = 10)
- Mental health (n = 7)
- Respiratory diseases (n = 9)
- Other chronic diseases apart from cardiorespiratory diseases (n = 5)
- Water-borne diseases (n = 6)
- Poisonings (n = 5)
- The burden of disease (n = 11)
- Vulnerable populations (n = 6)
- A review of all health impacts (n = 8)

Focus areas that respondents were not planning on researching in the future include: reproductive health and tight/sick building syndrome. It is interesting to note that researchers identified that a review of all climate change and health impacts has been previously researched with some researchers identifying that they are currently researching this. Researchers further noted that a review of all health impacts of climate change is a need for the future also. As the climate change field evolves with greater emphasis being placed on the adverse health impacts of climate change globally, it is necessary to keep reviewing the health impacts of climate change and updating provincial strategies as novel attribution research emerges.

Research Motivations

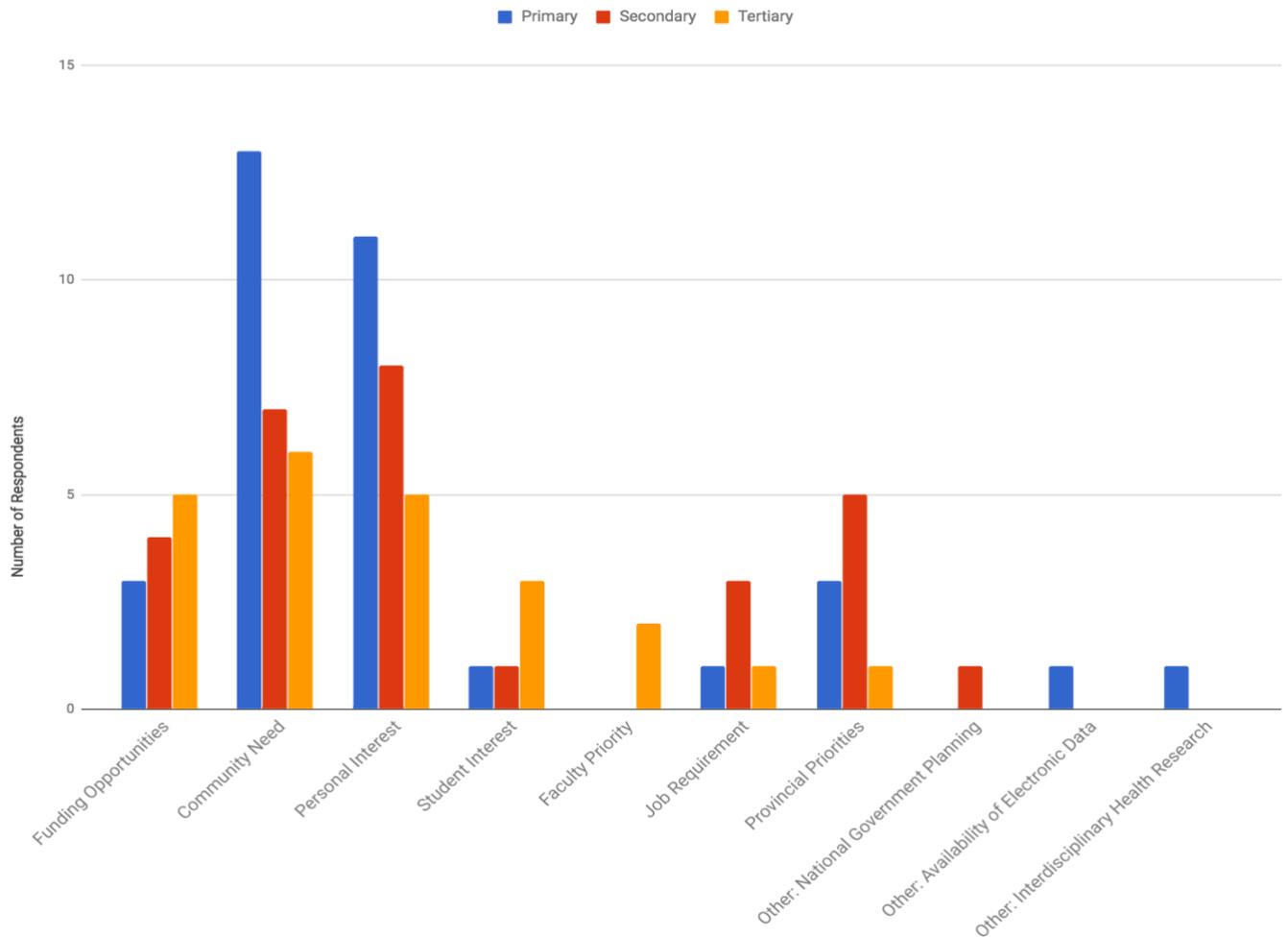


Figure 11: Factors driving climate-change and health research on the Western Cape (N = 31).

When asked about what factors drive research in climate-change and health, most respondents stated that the primary driving factor was community need and personal interest. Thus, if more researchers are needed for a specific topic, highlighting the community need would be an important aspect to add to calls for funding. For example, in the WC, further research is needed on heat-related illnesses and as researchers appear to be driven by community need, it would be valuable to highlight that the vulnerable group of agricultural workers with low adaptive capacity, who constitute 10.4% of the WC workforce (WCG, 2017) are at great risk of heat-related illnesses and deaths.

As an outcome of the survey, respondents were asked if they would be interested in joining an e-network for climate change and health researchers in the province, and 97 % of respondents stated they would join. The e-network could continue after the close of this project for structuring future research priorities and directions, increasing collaboration between researchers as well as increasing collaboration between universities and the WCG.

Gap Analysis

A comprehensive review of the literature was undertaken to identify all possible health impacts resulting from climate change locally and globally (Appendix 3). In addition to the research questionnaire, a search for research that was conducted only on the WC was undertaken. WC literature on climate change risk factors and health impacts was completed as well as searching university databases and

grey literature reports. A gap analysis for the WCG is presented in Table 1 below and identifies which general health topics are mentioned in the WCCCRS (2014), which topics are identified as gaps in knowledge requiring further research in the WCCCRS Biennial Monitoring and Evaluation Report (2015/2016) and finally, if our research and questionnaire identified any WC-focussed climate change researchers currently working on or planning to work on any health topics.

Table 1: Potential indirect risk factors and health impacts of climate change as identified from global and local literature with indications as to whether the Western Cape is addressing these issues.

Risk Factors and Health Impacts	WC Climate Change Response Strategy (2014)	WC Climate Change Response Strategy Biennial Monitoring and Evaluation Report (2015/16)	Researchers Identified Currently Working on this Topic or Planning to in the Future for the WC
Risk Factors			
Air pollution	✓	✓	✓
Ocean acidification	✗	✓ (not within the context of health, rather ocean life)	✗ (not within the context of human health)
Water quality and quantity	✓ (no mention of water-borne diseases)	✓ (mentions only cholera)	✓
Food security and food quality	✓ (minimal information on food quality)	✓ (minimal information on food quality)	✓
Labour productivity	✓	✓	✓
Ecological change	✓ (no mention of pests)	✓ (no mention of pests)	✓
Range and incidence of vectors	✓	✓	✓
Displaced communities	✗	✓ (mentions only population drift from rural to urban areas due to drought)	✗ (not within the context of human health)
Violence	✗	✓ (mentions that more research is needed)	✗
Socio-economic status	✓	✓	✓
Vulnerable groups	✓ (mentions only the elderly, poor health status and climate-sensitive occupations)	✓ (does not mention physically active, pregnant women, those living in urban heat islands, obese, disabled, mentally ill and socially isolated)	✓
Urbanisation and land use change	✓	✓	✓
Infrastructure and service delivery	✓	✓	✓
Health Impacts			
Hazard-specific mortality	✓	✗	✓
Injury	✗	✓	✓
Heat-related illnesses	✓	✓ (mentions that more research is needed)	✓
Cardiovascular disease	✗	✗ (mentions only "chronic diseases" in general)	✓
Respiratory disease	✗	✗ (mentions only "chronic diseases" in general)	✓
Renal disease	✗	✗ (mentions only "chronic diseases" in general)	✓
Mental ill-health	✗	✓ (mentions that more research is needed)	✓
Allergies	✗	✗	✓
Malnutrition	✗	✓ (mentions food security and states more research is needed on malnutrition)	✓
Communicable disease	✓	✓ (mentions that more research is needed)	✓
Food-borne diseases	✗	✗	✓
Water-borne diseases	✗ (mentions only water contamination by waste)	✓ (mentions only cholera)	✓
Vector-borne diseases	✓	✓ (mentions that more research is needed)	✓
Reproductive health	✗	✓ (mentions that more research is needed)	✗
Cancer	✗	✗	✓
Existing burden of disease	✓	✓	✓
Immune dysfunction	✗	✗	✓
Poisonings	✗	✗	✓

A tick (✓) indicates that the issue is mentioned, whereas a cross (✗) indicates the issue is not mentioned.

Figure 13 below indicates a summary of the results from the gap analysis conducted and highlights future areas of climate change and health research for the WCG. Areas of particular focus are those where a gap has been identified but where researchers are currently not focused on this topic as indicated by a star (*) in the figure below.

Climate Change and Health Research Gaps in the Western Cape

Risk Factors

Health Impacts

WCCCRS Monitoring & Evaluation Report 2015/2016 Research Gaps

- Occupational health specifically agricultural workers in the heat
- Violence*
- Transport infrastructure
- Resilience of human settlements and urban infrastructure

UCT-identified Additional Research Gaps

- Ocean acidification*
- Water quantity and quality such as *vibrio vulnificus* bacterial contamination*
- Food quality and nutrition insecurity
- Pests
- Displaced communities and environmental refugees*
- Vulnerable groups such as women and children and those living in urban heat islands

*no researchers currently focused on this topic in the WC

WCCCRS Monitoring & Evaluation Report 2015/2016 Research Gaps

- Heat-related illnesses
- Mental ill-health
- Chronic diseases
- Malnutrition
- Communicable diseases
- Vector-borne diseases
- Reproductive health*
- Women and child health

UCT-identified Additional Research Gaps

- Hazard-specific mortality
- Cardiovascular diseases
- Respiratory diseases such as COPD*
- Renal diseases
- Allergies
- Food-borne diseases such as campylobacteriosis and listeriosis*
- Cancer
- Immune dysfunction
- Tight/sick building syndrome*
- Musculoskeletal health
- Poisonings
- Vulnerable populations
- Motor vehicle accidents*
- Emerging vector-borne diseases e.g. African trypanosomiasis, leptospirosis, dengue, Crimean-Congo haemorrhagic fever*
- Emerging infectious diseases such as TB, meningitis, hand, foot and mouth disease*
- Pests as vectors of disease particularly flies*

Figure 12: Climate change and health research gaps for the Western Cape.

RECOMMENDATIONS FOR FOLLOW-UP ACTION

Overall, it is recommended that more research is conducted to understand whether climate is playing a significant role in several health cases identified in the WC recently such as the listeriosis outbreak and the *vibrio vulnificus* bacterial mortality incident mentioned earlier in this document. Thus, we state that climate change should be included in all health issues and planning similarly to how the American Public Health Association advocates for climate change to be included in all health research. In this way WCG monitoring and surveillance systems and processes would become proactive in screening health issues for a climate change influence, rather than reactive. For this to be effective, the WC: DoH requires access to climate information and data to allow capacity to make climate connections.

It is also recommended that an extended review of health impacts, such as the one conducted for temperature (Appendix 4), be conducted for all climatic projections as well as direct and indirect risk factors identified. It is recommended that, for some diseases, disease repositories in the region, and the regions bordering the area (particularly with potential geographic expansion of some vectors), should be consulted to check if the disease has occurred in the region recently such as within the last 10 years (e.g. Dengue Fever in the WC) and it is also useful to consult with the health experts on the PSG for disease prevalence.

As indicated in the Lancet Countdown on Health and Climate Change (2017), climate change should feature more prominently in professional health education. Walpole et al. (2017) argue that an environmentally accountable medical curriculum enables future health professionals to appreciate and understand the interaction of ecosystems and human health. It is through the inclusion of environmental health into the medical curriculum that students can become agents and advocates of change. As an example, at the University of Cape Town, the teaching time of climate change and health totals one hour in a six-year medical curriculum. This is not sufficient to impart climate change and health urgency and impact. Organizations such as the International Federation of Medical Students' Associations have developed useful materials such as the Climate and Health Training Manual for students and young professionals which includes sections on knowledge and capacity building. [EcoAmerica](#) have created a guide on communicating health and climate for health professionals and includes successful messages and key talking points around the topic. It is vital to integrate health into the climate change conversation and educating health professionals and medical students on the health impacts of climate change is imperative for the province.

The WCG and WC-focused policy initiatives should remain cognizant that climate change will disproportionately impact on vulnerable groups and climate change preparedness strategies should address this. Specific outreach activities, communication campaigns and health promotion strategies on climate change impacts on health should target vulnerable groups and ideally, vulnerable group-sensitive early warning systems, forecasting, surveillance and monitoring should be implemented in the WC.

Indeed, future research should focus on the priority focus areas identified in Figure 13.

Priority Focus Areas for the Western Cape

Through this review of the global, national and provincial literature, as well as the results from the research questionnaire, a number of priority research focus areas have become apparent for the WCG (Figure 13). Due to time constraints, only some of these research gaps and are discussed in detail below.

Heat Strain in Outdoor Workers Wearing Protective Equipment

Outdoor workers in South Africa operate in an environment that presents thermal challenges such as high ambient temperatures, often over 30 °C, and humidity with a high radiant heat load from the sun. Some workers are required to wear personal protective equipment (PPE) to protect themselves against exposure to hazardous chemicals, such as herbicide applicators of the South African Working for Water (WfW) programme under the Department of Environmental Affairs (DEA). PPE however, can impair an individual's ability to thermoregulate (i.e. regulate one's body temperature) and increases a worker's vulnerability to suffering heat illness, injury and heat stroke that can be fatal. Even if heat symptoms and illnesses are not life threatening, it might result in increased absenteeism, placing a socio-economic strain on workers. The South African Long-Term Adaptation Scenarios document (DEA, 2013) explicitly calls for increased research on high temperatures and health impacts on South African populations which is also echoed in the draft of South Africa's Third National Communication under the United Nations Framework Convention on Climate Change (2017). Additionally, the International Labour Organization and United Nations Development Programme explicitly state in their key findings and policy recommendations of the document, *Climate Change and Labour: Impacts of Heat in the Workplace* (2016), that more detailed research and analysis of workers exposed to increased heat is urgently required. The Division of Environmental Health at UCT has the technical skills and ability to conduct an assessment of physiological strain and hydration status of outdoor workers wearing personal protective equipment in the heat.

Violence and the Urban Heat Island Effect

South Africa ranks 4th (out of 115 countries) for the world's highest crime index rating, with Cape Town ranking 22nd (out of 327) for the world's cities with the highest crime index (Numbeo, 2018). As mentioned above, climate change and an increasing temperature will very likely worsen interpersonal violence and crime rates (Auliciems & DiBartolo, 1995; Collings, 2008; Breetzke & Cohn, 2012; Ranson, 2014; Breetzke, 2015; Mares & Moffett, 2016). There has been no research in the WC on violence and climate change and furthermore, globally there has been no research conducted on how violence could be exacerbated with the dual threat of increasing temperatures and urban heat islands. Fuelled by socio-economic strife and poor building materials of corrugated iron, the impact of climate change on levels of violence in poor urban areas, could be a significant future concern for the province and should be thoroughly investigated. The LTAS (DEA, 2013) acknowledges heat-related violence as a psychosocial issue and the WCCCRS Biennial Monitoring and Evaluation Report (2016) calls for an increased awareness on climate change and violence. However, neither document, nor any other provincial or South African official document, provides any detail on climate change impacts on violence. Permitting access to South African Police records, the Division of Environmental Health at UCT has the technical skills and capacity to conduct this research.

Child and Gender-focussed Research and Strategies

Rother (2017) considers the issues of children as the "canary in the mineshaft" when it comes to action on the health impacts of climate change stating that the long-term health impacts of climate change might only manifest later in adulthood after children have been exposed. Rother (2017) asserts the position that children are not "little adults" but are rather uniquely vulnerable to health outcomes as a result of climate change due to their physiology and behaviours differing from adults. It is vital that policy makers consider the long-term health impacts of climate change and the specific vulnerabilities of children through adopting the precautionary principle when formulating policies.

The South African Department of Environmental Affairs and the Department of Women, Children and People with Disabilities in collaboration with UNICEF created an exploratory report on the impact of climate change on children in the country (UNICEF, 2011). A similar exploratory analysis should be conducted specifically for the WC to determine how the region's children might be impacted by climate change. Importantly, the national report also considered children's voices on climate change in a

participatory process in policy development and includes sections on children’s roles and recommendations in tackling climate change. This method of empowerment often results in children having a sense of ownership over creating solutions for the challenge of climate change. It is recommended that a similar project is undertaken by the WCG.

In addition, as women and children are particularly vulnerable to the impacts of climate change, gender-specific issues should be mainstreamed into health adaptation climate change programmes. The conceptual framework presented below in Figure 14 describes how gender differences might result in different risk factors, vulnerabilities and health outcomes (WHO, 2012). These should be considered within research projects conducted in the WC but also when designing strategies and policies around health and a changing climate.

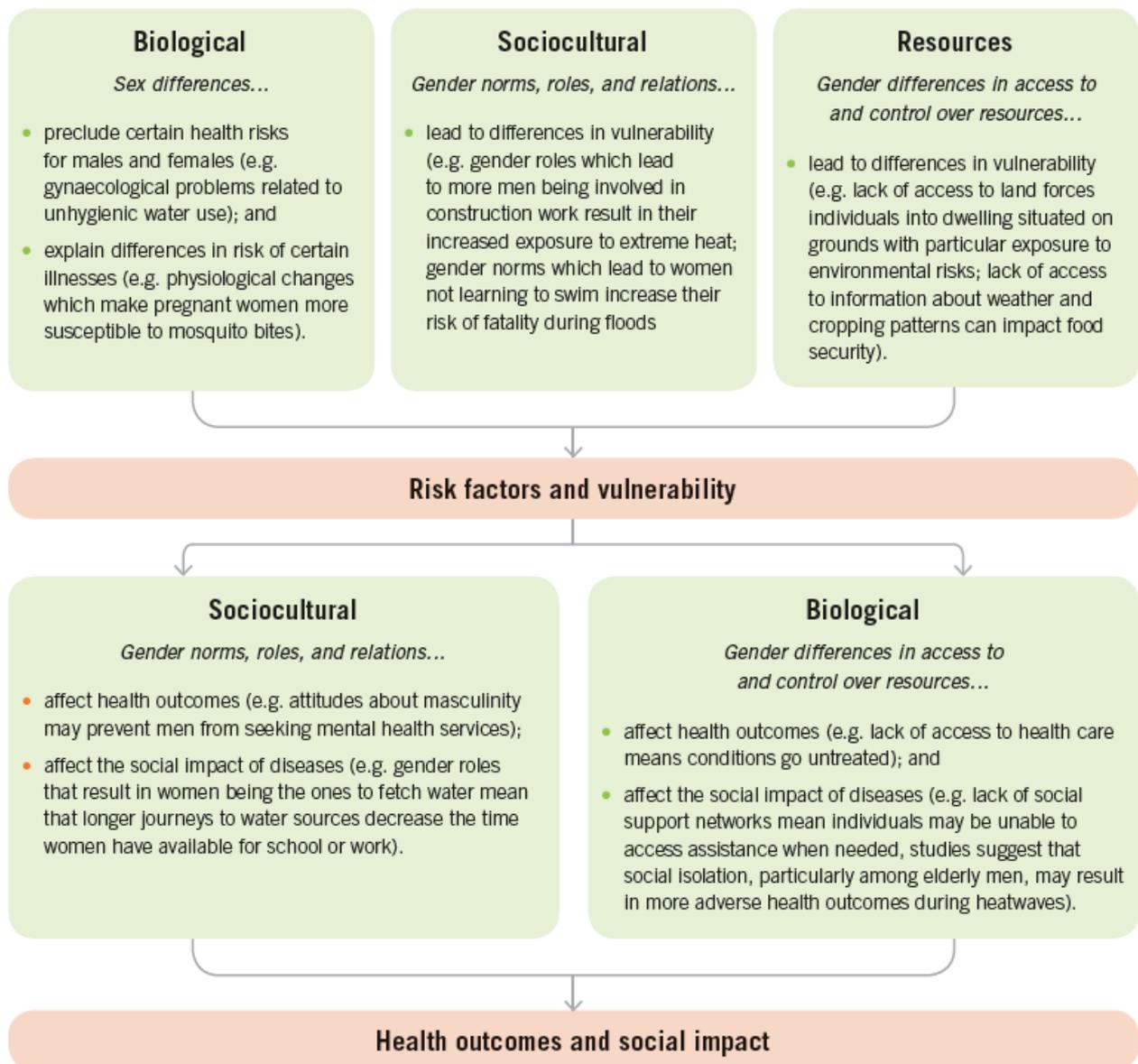


Figure 13: Conceptual framework of gender vulnerabilities in relation to health outcomes of climate change (WHO, 2012).

Burden of Disease

The “neon effect” states that climate change is likely to exacerbate the existing burden of disease in a country, yet few research has centred around this concept. The burden of disease can be analysed in various ways. To prevent a bias from diseases that are most common in the elderly, premature mortality is calculated by the years of life lost (YLL) *i.e.* which diseases cause the greatest shortening of life. Due

to data availability from death notification forms, YLLs for the leading causes of death in the WC for 2009 - 2013 were compiled by Morden et al. (2016) and are illustrated in the figure below.

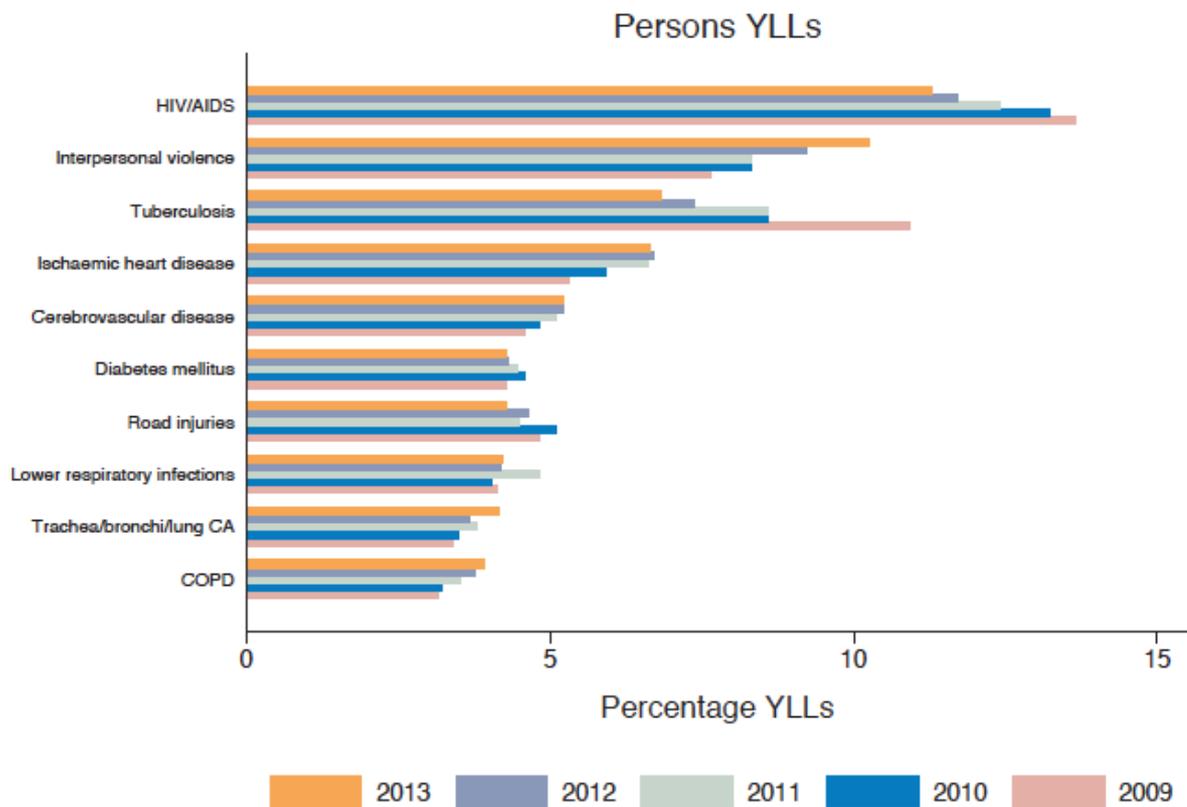


Figure 14: Years of life lost for all persons in the Western Cape between 2009 – 2013 (Morden et al., 2016).

For most areas, climate change is unlikely to introduce many new diseases, but will instead worsen the current disease burden (Myers, 2012). The geographical range of certain disease-carrying vectors could change due to a changing climate and thus new diseases might be introduced to locations bordering already disease-affected areas (Reiter, 2008; Niang *et al.*, 2014). Nonetheless, it is vital to consider the current burden of disease in the WC in relation to climate change predictions; the top three diseases are considered below.

HIV/AIDS

The links between climate change and HIV/AIDS are mostly indirect, particularly through that which affects food security (Anema et al., 2009) and population displacement (Myers et al., 2011). As climate change is likely to exacerbate food insecurity, not only will the nutrition of people living with HIV/AIDS be compromised (Drimie and Gillespie, 2010) but their adherence to medication may also suffer (Olupot-Olupot et al., 2008; Sanjobo et al., 2008) and their progression to AIDS hastened (Drimie and Gillespie, 2010). There may be increased risk-taking behaviours that increase HIV transmission (Anema et al., 2009). Dunkle et al. (2004) found that amongst a cohort of South African women presenting at antenatal clinics in Soweto, some women participated in transactional sex for, *inter alia*, food, clothing, transport, accommodation and school fees. Fiorella et al. (2015) investigated transactional sex relationships during times of food insecurity in Kenya and identified pathways in which declining fish stocks could increase HIV risk through fish-for-sex relationships. Malnutrition can also increase the risk of HIV infection through a compromised immune system (Gillespie et al., 2001) and increase the risk of mother-to-child transmission (Mehta et al., 2008).

Individuals burdened with HIV/AIDS also exhibit a diminished capacity to cope with the effects of climate change, lowering resilience and increasing their and their family's vulnerability to climate change (Drimie and Gillespie, 2010). Population displacement leading to environmental refugees creates difficulties in accessing adequate health care (Drimie and Gillespie, 2010) as well as increased risk of HIV infection among migrants (Zuma et al., 2003). Having HIV/AIDS might also place individuals in a poverty-disease trap, particularly given the cost of treatment as well as a decreased work productivity (Costello et al., 2009), which again increases vulnerability to the hazards of climate change and hampers adaptive capacity.

Coinfections with diseases such as malaria results in pathological interactions that increase the HIV viral loads, which in turn increases transmission and HIV disease progression (Abu-Raddad et al., 2006; Talman et al., 2013). Furthermore, HIV infection increases the susceptibility to malaria infection (Abu-Raddad et al., 2006). Fever is a common symptom of many infections including HIV (Anglaret et al., 2002), which will result in HIV-infected individuals operating at higher internal temperatures for the same amount of work as those without fever. Furthermore, although not widely researched, it has been suggested that prolonged extreme heat exposure can depress the immune system (Gleeson, 2007) thereby increasing susceptibility to other infections and fever (Nwanyanwu et al., 1997), placing these already vulnerable individuals at further risk of developing heat illness. Finally, as HIV depresses the immune system, infected individuals are vulnerable to contracting opportunistic gastrointestinal tract infections leading to diarrhoea as a common comorbidity of the disease (Lew et al., 1997). Diarrhoea and associated dehydration reduce an individual's adaptive capacity and tolerance for developing heat illness. HIV infection is the highest ranked burden of disease in the province and more research is needed on how climate change will affect HIV infection rates as well as further research on the vulnerability of HIV-infected individuals to a changing climate.

Interpersonal Violence

Ranson (2014) extrapolated that between the years 2010 and 2099 climate change would result in additional homicides (22,000), rapes (180,000), robberies (260,000) and assaults (2.3 million) in the USA alone. This was based on regression analysis of monthly crime reports and weather data (precipitation and temperature) in 2997 US counties. Although these statistics are for the USA, according to the United Nations Office on Drugs and Crime, currently South Africa has a murder rate that is approximately seven times higher than the USA and, whilst the relationship is not linear, this provides an indication as to the possible extent of the impact in the region. The temperature-aggression hypothesis seeks to explore the physiological and psychological mechanisms underpinning the clear relationship between heat and aggression (Anderson, 1989). Possible theories include: thermoregulatory (neural and hormonal systems), negative affect and excitation-transfer (Anderson, 1989).

Amongst the most vulnerable to interpersonal violence are women and children (WHO, 2014). Collings (2008) reported that, in KwaZulu Natal, child rape was elevated in summer compared to winter and also made reference to the temperature/aggression theory. During times of drought and water stress and the subsequent loss of family livelihoods, children may drop out of school and take to the streets to beg for food or do dangerous jobs to provide for their families (Save the Children, 2012). During times of climatic extremes or stress, children are often left unprotected and can be exposed to exploitation as their guardians' search for food or work. A study conducted in Brisbane, Australia, found a relationship between maximum air temperature and emergency calls to the police of domestic violence, again highlighting the vulnerability of women in a changing climate (Auliciems and DiBartolo, 1995). As acts of violence are often heavily concentrated in urban areas (Mares and Moffett, 2016), it is plausible that there may be an even greater increase in interpersonal violence in response to elevated temperatures due to the urban heat island effect, thus making urban residents more vulnerable than

non-urban residents to temperature-induced aggression. As vulnerability of women and children is so intricately linked to this issue, further research is critical for the WCG.

Tuberculosis

The WC has the highest rate of TB in South Africa (703 cases per 100,000 people) (WCDoH Annual Report 2014/2015) and, as noted in the WCCCRS (2014), individuals suffering with chronic disease or illness such as TB are vulnerable to climate change-related risks and subsequent adverse health impacts due to a poor adaptive capacity. Globally, whilst infectious diseases are often a prominent concern in the climate change literature, TB is rarely reviewed within this context. Makri and Stilianakis (2008) found that individuals with pre-existing cardiorespiratory conditions and those who are socio-economically deprived, are at greater risk of air pollution-related mortality and morbidity. Often in LMICs, biomass and kerosene are used as fuels for cooking and heating and degrade indoor air quality when burned, which is a risk factor for TB (Pokhrel et al., 2010). High levels of air pollutants in combination with winter temperature inversions adversely affect respiratory conditions and decrease lung function, subsequently increasing susceptibility to respiratory infections (Abayomi & Cowan, 2014).

Climate change is projected to worsen food insecurity and without adequate nutrition, the immune system is impaired, increasing the susceptibility to opportunistic infections such as TB (Woodward, 1998; Cegielski & McMurray et al., 2004). Furthermore, to combat an infection, the body requires greater nutritional sustenance and it should be noted that TB infection itself can deprive an individual of nutrients resulting in cachexia (Scrimshaw et al., 1968; Schaible & Stefan, 2007). TB is a common comorbidity of HIV infection, which severely affects an individual's immune system (Abayomi & Cowan, 2014). Often living with a severe chronic disease such as TB places individuals in a poverty trap resulting in financial instability and exacerbating food pressures and malnutrition, particularly in a situation where there is little support from the health system and/or there is political unrest (Schaible & Kaufmann, 2007). Another climate-related risk factor for exacerbating the prevalence of infectious diseases such as TB, is population displacement and urban migration, likely outcomes of extreme weather events and climate change (Watts et al., 2017). Research using satellite imagery has shown that large populations are vulnerable to infectious diseases particularly when the healthcare infrastructure is not adequate (Ford et al., 2009).

Although not a prominent discussion in global climate change and health literature, given that TB is the third greatest disease burden in the WC, further research is vital on climate change-related risk factors for TB prevalence and spread. In Japan, Onozuka and Hagihara (2015) found an increased relative risk (ratio of the probability of occurring) of 1.20 (CI: 1.01 – 1.43) in the number of TB cases in relation to extreme heat days and an increased relative risk of 1.23 (CI: 1.05-1.45) in relation to extreme cold days. Seasonal changes in childhood TB in the Cape Town area have been noted with increased transmission in winter possibly associated to poor living conditions in winter (Schaaf et al., 1995) but the cases were not correlated against climate data or extreme weather events. Given the burden of disease of TB on the WC a study with a similar methodology as Onozuka and Hagihara's (2015) study should be conducted urgently for the region with suggested public health adaptation intervention options.

CONCLUSIONS

This review of literature highlights climate change-related direct and indirect risk factors and health impacts of interest to the WCG health sector and has emphasised vulnerable populations of concern as summarized in Figure 16. A number of future research areas were identified that coincide with current global research around climate change and health. There are seven key highlights that have arisen from this research project:

1. Both direct and indirect (environmental and social) risk factors should be addressed in future policy decisions to reduce the prevalence of climate change-related health outcomes.
2. The WCCCRS (2014) update needs to include the following climate change-related adverse health outcomes: injury, NCDs, mental ill-health, food and nutrition insecurity-related diseases, water-borne diseases and reproductive health.
3. Specific outreach activities, communication campaigns and health promotion strategies on climate change impacts on health should target vulnerable groups (i.e. outdoor workers, children and women) and ideally, vulnerable group-sensitive early warning systems, forecasting, surveillance and monitoring should be implemented in the WCG.
4. Priority focus areas for the WCG include the health impacts of climate change-exacerbated burden of disease, vulnerable populations (e.g. outdoor workers, women and children), violence, ocean acidification, reduced water quality and water scarcity, environmental refugees, reproductive health, NCDs, food-borne diseases, motor vehicle accidents, emerging vector-borne diseases, emerging infectious diseases and pests as vectors of disease.
5. The impacts of climate change on human health should feature more prominently in health professional's education curriculum.
6. The WCG should create adaptation and mitigation strategies and projects that are viewed through a health lens at the initial formation stages of projects such that there is "health and climate change in all policies".
7. The WCG should consider creating a database, such as that contained within this report (Appendix 11), of global success stories of adaptation and mitigation intervention strategies that elicit co-benefits which can be reviewed during future strategic adaptation planning for the province.

Climate Change

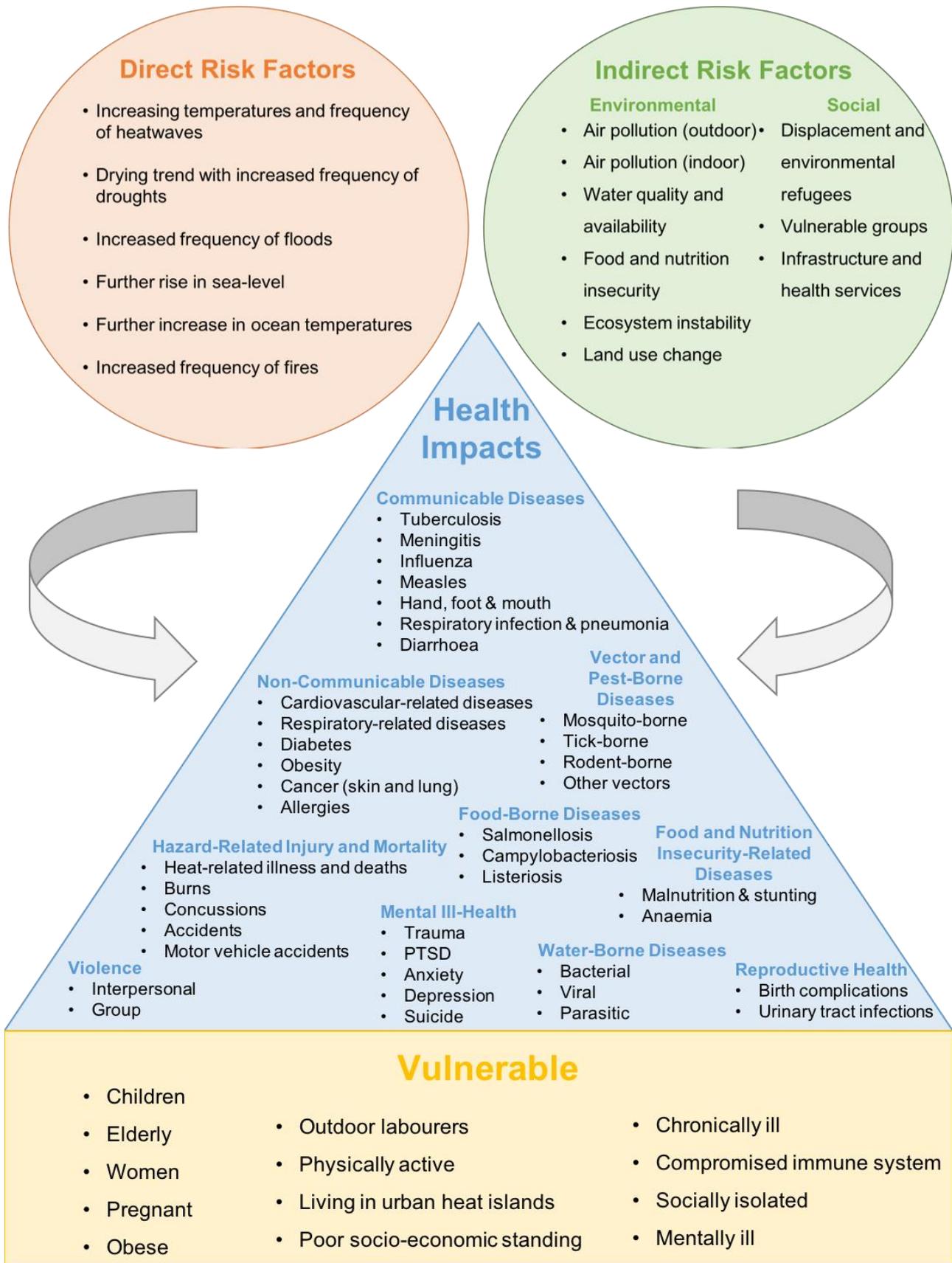


Figure 15: Climate change-related risks and health outcomes.

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APPENDICES

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Appendix 12: Global examples of programmes addressing environmental health risk factors exacerbated by climate change for the Western Cape Government to review

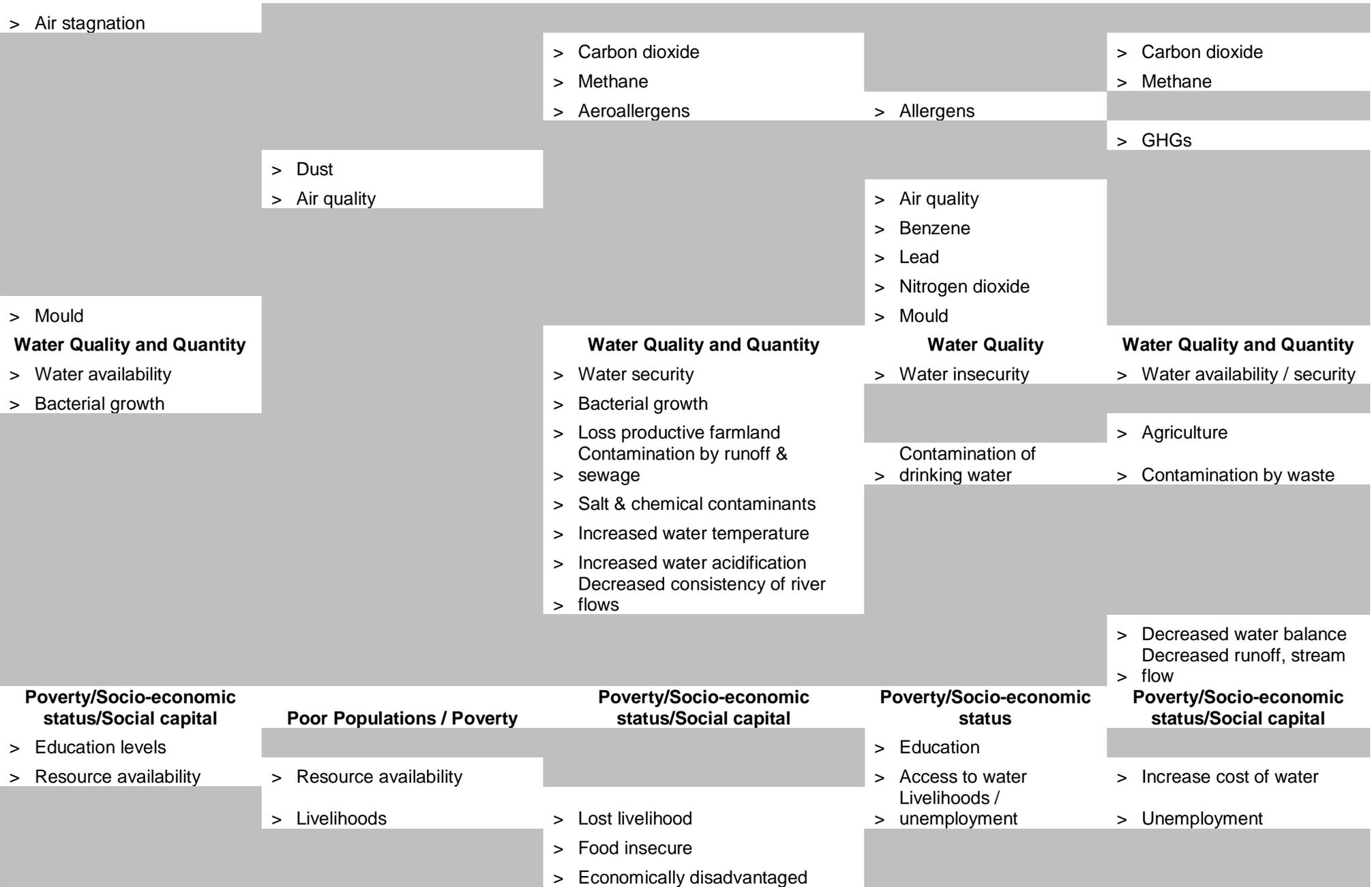
Appendix 1: Project steering group members

Professor Hanna-Andrea Rother	University of Cape Town (Division of Environmental Health)
Dr Christie Godsmark	University of Cape Town (Division of Environmental Health)
Mr James Irlam	University of Cape Town (Primary Health Care)
Mr Goosain Isaacs	Western Cape Department of Environmental Affairs and Development Planning
Ms Frances van der Merwe	Western Cape Department of Environmental Affairs and Development Planning
Dr Bart Willems	Western Cape Department of Health
Professor Mark New	University of Cape Town (African Climate and Development Initiative)

Appendix 2: Scoping review of climate change risk factors

Scoping Review of Risk Indicators				
GLOBAL Watts et al. (2015)	AFRICA Niang et al. (2014)	SOUTHERN AFRICA Myers et al. (2011)	SOUTH AFRICA DEA (2013)	WESTERN CAPE WCCCRS (2014)
Extreme Weather Events	Extreme Events	Extreme Climatic Events	Natural Disasters/Extreme Events	Extreme Events
> Heatwaves	> Heatwaves	> Heatwaves	> Heatwaves	> Heatwaves
> Storm			> Storms	> Storm surges & flash flood
> Fire		> Fire	> Fire	> Fire
> Heavy precipitation & flood	> Heavy rainfall & flooding	> Flood	> Flood	> Heavy precipitation & flood
> Drought		> Drought	> Dry spells / drought	> Drought /drying
> Hurricanes		> Hurricanes		
> Cyclones			> Cyclones	
> Typhoon				
> El Nino	> El Nino Southern Oscillation		> El Nino	
	> La Nina			
	> Indian ocean dipole			
> Monsoon				
> Cold	> Low ambient temperatures	> Cold		> Cold snaps
	> Winds		> Wind	> High winds
		> Smog	> Smog	
			> Landslide/mudslides	
			> Tsunami	
			> Snow	
			> Lightning	
				Winter Rainfall Area
Temperature	Temperature	Increased Temperature	Temperature	Increased Temperature
> Vector-borne disease	> Vector-borne disease			
				> Higher evaporation rates
		> Food-borne infections		

		> Occupational health Participation in strenuous outdoor > activity		
	> Water temp of breeding sites > Sea temperature		> Water surface temp Sea surface > temperature	
Altered Patterns of Precipitation	Humidity	Increased Humidity	Relative Humidity	
	Precipitation	Altered Patterns of Precipitation	Rainfall	Altered Patterns of Precipitation
		> River flows		> Drying
			> Pressure > Cloud cover	
Sea Levels		Sea Levels	Sea Level Rise	Sea Level Rise
> Saline water intrusion > Vector-borne disease		> Saline water intrusion		> Saline water intrusion
				Impacts on estuaries and > fish > Coastal infrastructure
Ocean Acidification Fishing & aquaculture > productivity				
Air Pollution	Air Pollution	Air Pollution	Air Pollution	Atmosphere Pollution
> Pollen allergenicity		> Air-borne pollens & spores	> Pollens & spores	
> Particulate pollution	> Particulate matter		> Particulate matter	
> Indoor air pollution Ground-level ozone > increase	> Smoke cooking fires			
> Nitrogen oxides	> Ozone	> Ground-level ozone	> Ozone	
> SO2			> Nitrogen dioxide	
> Carbon (black and organic)			> SO2	Carbon emissions / > footprint
> Aerosols	> Aerosols			
> Carbon monoxide from fires	> Carbon monoxide		> Carbon monoxide	



- Transactional sex, commercial
- > sex work & partner numbers
- > Risk taking behaviour

- > Sanitation
- > Access to safe water

- > Sanitation

- > Informal settlements
- > Sanitation

- Informal settlements /
- > Apartheid planning

- > Access to air conditioners

Mass Migration / Population Density / Growth

- > Cultural identity
- > Impaired air quality
- > Security

Migration

Population Migration

Forced Migration / Population Density / Growth

- > Interpersonal violence
- > Refugee pressures
- > Social tension

- > Environmental refugees

- > Overcrowding

Violent Conflict & Human Security

- Perception of insecurity/safety
- >

Violent Conflict & Human Security

Violence and Conflict

- Behaviour
- > (accidents/aggression/risk taking)
- > Access to crops, land & water
- > Civil & military violence
- > Gender violence

- Conflict over limited resources
- >

Food Security/Undernutrition

- > Food availability
- > Food affordability
- > Crop yield
- > Agricultural productivity

Food Insecurity

- > Food accessibility

Food Security/Undernutrition

- > Food yield
- > Agricultural yields

Food Security

- Food
- > availability/accessibility
- > Food prices
- > Crop yield
- Agricultural yields
- > /productivity

Food Security/Undernutrition

- > Crop yield
- > Agricultural productivity



- > Shrews & moles
- > Tsetse fly

- > Landslide

- > Fish populations
- > Coral reef damage

- Coastal barrier dunes / infrastructure
- > Wetlands
- > Flood plains
- > Soil/river bank erosion
- > Urban-induced soil erosion
- > Fish & marine species
- > Heat stress in wildlife
- Drying impact on river ecosystem
- > Coastal erosion
- > Estuaries

- Vector
- > ecology/abundance
- Environmental
- > resources

Health status	Population Susceptibility	Health status	Health status
Existing health status/disability	> Existing health status	Existing health status/disability (chronically ill/immunocompromised)	Existing health status/disability
> BoD			> BoD
Reduced physical work capacity	> Work capacity loss	> Workplace productivity	
		> Taking medication	
Incidence & Geographical Range Infectious Diseases	Incidence & Geographical Range Infectious Diseases	Incidence & Geographical Range Infectious Diseases	Incidence & Geographical Range Infectious Diseases
Distribution of disease	Distribution of disease	Density & movement of disease	Distribution of disease
> vectors	> vectors	> vectors	> vectors
Reproductive rates and lifecycles	Production of immature mosquitoes	> Vector populations and habits	> Vector abundance
	> Parasite prevalence	Infectious agents (dengue, bacteria, protozoans)	

	> Species composition			
Biological Factors		Vulnerable Populations	Vulnerable Groups	Biological Factors
> Age (elderly and young)	> Age (children)	> Age (elderly & children)	> Age (children & elderly)	> Age (elderly)
> Gender	> Gender (women)	> Gender (women)	> Gender (women)	
		> Pregnant women	> Rural communities	
			> Socially isolated	
Technology				
Governance Structure	Poor Governance			
Urbanisation			Urbanisation	Urbanisation
> Heat island effect				> Urban heat island effect
				> Storm water systems
				> Urban management
Public Health Infrastructure		Public Health Infrastructure		
	Access to healthcare facilities	> Quality, availability & readiness		
	> facilities	> Disease surveillance		
		> Health promotion		
		> Community mobilization		
	> Early warning systems	> Disaster preparedness	> Disaster preparedness	Increased Pressure on Disaster Relief Systems
		> Emergency service response		
		Training of emergency and health personnel		
	> Healthcare systems	> Programme evaluation	Condition of healthcare systems	
	> Adaptation & mitigation	Adaptation & mitigation research & innovation	> systems	
	Inadequate housing facilities			
	> e.g. Mosquito protection			
	Infrastructure	Infrastructure	Infrastructure	Infrastructure
				Increased electric cooling demand
		Damage to essential infrastructure		> demand
	> e.g. transport	> Damages	> Damages	> Damages

- > Coastal, urban, low-lying, islands, vector border regions
- > Quality of water and sanitation
- > Quality of roads and transport
- > Fuel availability

- > Coastal flooding
- > Sewerage
- > Access to services

- > Coastal properties
- > Access to roads

> Rural areas

- > Rural and urban settlements

- Critical infrastructure
- > hotspots
- > Drainage networks
- > Rural human settlements
- Flood-prone areas & sand dunes
- > Inferior building materials
- > Energy security

- > Built environment

Water resource development
> e.g. dams & schistosomiasis

- > Ultra-violet radiation

Tourism

Risk to Economy/Financial Burden

- Emergency response capacity / Service
- > Delivery

- > Service delivery
- > Land management

Substance Misuse

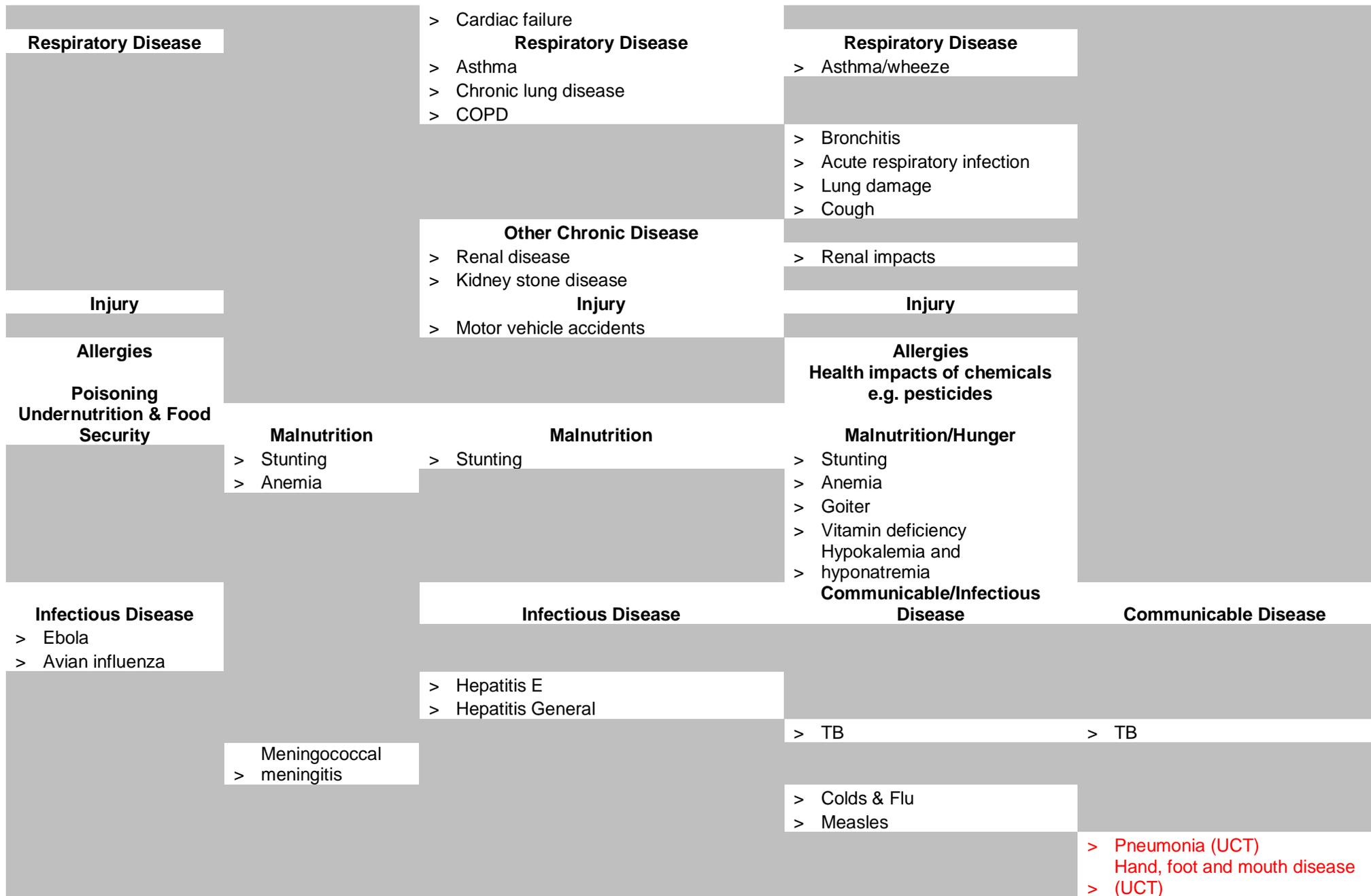
- > Alcohol
- > Narcotics

Substance Abuse

- > Alcohol

Appendix 3: Scoping review of climate change health impacts

Scoping Review of Risk Indicators				
GLOBAL Watts et al. (2015)	AFRICA Niang et al. (2014)	SOUTHERN AFRICA Myers et al. (2011)	SOUTH AFRICA DEA (2013)	WESTERN CAPE WCCCRS (2014)
Mental Health		Mental Health	Mental Health	
> Depression		> Depression	> Depression	
> Anxiety		> Anxiety	> Anxiety	
> Solastalgia			> Chronic psychological distress	
> Chronic distress				
> Suicide		> Suicide		
> PTSD		> PTSD	> PTSD	
		Trauma due to loss (people & property) & displacement	> Trauma	
			Behavioural problems/mood disorders	
		> Mood	> Cognition	
			> Somatoform	
			> Apathy	
			> Helplessness	
			> Grief	
Death		Death	Mortality/Loss of Life	Loss of Life
	Heat-related Health Effects	Heat-related Illness	Heat Stress	Heat Stress
Heat Stress		> Dehydration	> Dehydration	
> Dehydration		> Morbidity & mortality	> Morbidity & mortality	> Morbidity & mortality
> Morbidity & mortality	> Mortality & morbidity	> Heat cramps	> Heat fatigue	> Heat-related illness
		> Heat exhaustion		
		> Heat syncope		
		> Heat stroke		
Cardiovascular Disease		Cardiovascular Disease	Cardiovascular Disease	
> Obesity			> Diabetes	
> Diabetes				
> Coronary heart disease				
> Stroke		> Stroke	> Cerebrovascular Disease	



Water-Borne Disease	Water-Borne Disease	Water-Borne Disease	Water-Borne Disease	
> Cholera	> Cholera	> Cholera	> Cholera	
			> Typhoid	
> Bacterial diarrhoea	Diarrhoeal diseases	> Diarrhoeal diseases	> Diarrhoeal diseases	
		> Hepatitis A		> Legionnaires' disease (UCT)
	Food-Borne Disease	Food-Borne Disease	Food-Borne Disease	
		> Salmonella	> Salmonellosis	
Vector-Borne Disease	Vector-Borne Disease	Vector-Borne Disease	Vector-Borne Disease	Vector-Borne Disease
> Dengue		> Dengue Fever	> Dengue Fever	
> Malaria	> Malaria	> Malaria	> Malaria	> Chikungunya fever (UCT)
> African trypanosomiasis	African trypanosomiasis			
> Lyme disease	Tick-borne diseases		> Tick bite fever /Lyme Disease	
> Schistosomiasis	> Schistosomiasis		> Schistosomiasis	
> Hantavirus	> Hantavirus			
> West Nile Virus		> Tick-borne encephalitis		
		> Plague		
	> Leishmaniasis			
	> Rift valley fever		> Yellow fever	> Leptospirosis (UCT)
		Other Water Illnesses		Crimean-Congo Haemorrhagic fever (UCT)
		> Ear, nose and throat		
		> Skin	> Skin irritations & dermatitis	
		> Gastro-intestinal	> Gastro-intestinal	
		> Giardiasis		
		> Cryptosporidiosis		
			> Eye irritation	

		Reproductive and Developmental Effects	
			> Urinary tract infections (UCT)
		Cancer Risk	
		> Skin Cancer	
		> Lung Cancer	
	Amplification of Existing BoD Sexually Transmitted Infections		Existing BoD Vulnerability
> HIV/AIDS	> HIV	Sexually Transmitted Infections	> HIV/Aids
		> HIV/Aids	
		Immune dysfunction	
		> Autoimmune disease	
		Musculoskeletal Disorders	
		Tight building syndrome	
	Health Benefits	Health Benefits	Health Benefits
	> Warmer winters		Reduce risk cold-related
			> deaths

Appendix 4: Extended review of climate change-related health outcomes (temperature only)

Temperature Increase			
Western Cape Burden of Disease	IPCC Confidence Intervals (Global Health and Africa Health Chapter)	Other based on Research (Framework for Search from Indicator Review)	
Increased hospital visits for respiratory disease ^[1]	LIKELY, ROBUST EVIDENCE, VERY HIGH CONFIDENCE Heat-related illnesses, including heat stroke, heat exhaustion, heat cramps, heat syncope, heat exhaustion and heat-related mortality ^[2, 16, 18]	Increased hospital admissions for asthma ^[22]	Increased diagnoses of Grave's Disease ^[39]
Increased risk of pneumonia ^[51]	ROBUST EVIDENCE in countries with endemic cholera Increased incidence of cholera ^[64]	Increased allergic rhinitis ^[35]	Increased incidence of meningitis ^[62]
Increased COPD morbidity ^[25]	VERY HIGH CONFIDENCE Increase in injuries ^[26]	Increased hospital visits for electrolyte imbalances ^[5]	Increased number of hospital visits for diarrhoea ^[40]
Increased hospital visits for cardiovascular diseases ^[5]	HIGH CONFIDENCE with high humidity Increased undernutrition ^[36]	Increased risk of mortality from suicide ^[3]	Increased incidence of measles ^[68]
Increased incidence of cerebrovascular disease ^[21]	HIGH CONFIDENCE in global effect Increased incidence of dengue ^[41]	Increased hospital admissions for dementia ^[12]	Increased incidence of chikungunya ^[72]
Increased hospital visits for diabetes ^[58]	HIGH CONFIDENCE in local effect Increased malaria transmission ^[71]	Increased hospital admissions for mood disorders ^[12]	Increased incidence of yellow fever ^[75]
Increased risk of violence ^[6]	LOW CONFIDENCE in effect Increased incidence of tick-borne encephalitis ^[77]	Increased emergency department visits for mental and psychosocial problems ^[52]	Increased incidence of African trypanosomiasis ^[73]
Increased incidence of tuberculosis ^[66]	LOW CONFIDENCE in effect Increased incidence of Lyme borreliosis ^[78]	Increased psychological distress ^[20]	Increased incidence of leptospirosis ^[65]
Increase in severe influenza epidemics with early onset ^[67]	HIGH CONFIDENCE in local effect Increased incidence of Hemorrhagic fever with renal syndrome ^[74]	Increased major depressive episodes ^[53]	Increased risk of schistosomiasis infection ^[42]
Increased risk of motor vehicle crashes ^[60]	LOW CONFIDENCE in effect Increased incidence of human plague ^[43]	Increased hospital admissions for somatoform disorders ^[12]	Increased transmission of West Nile Virus ^[44]

	Increased mortality from mental and behavioural disorders ^[12]	Increased cryptosporidiosis notifications ^[45]
	Impairment of cognition, reaction time and attention ^[55]	Increased incidence of giardiasis ^[76]
	Increased risk of renal dysfunction ^[4]	Increased incidence of hand, foot & mouth disease ^[61]
	Increased risk of kidney stones ^[17]	Increased incidence of Legionnaires' Disease ^[70]
	Increased incidence of salmonella food poisoning ^[30]	Increased incidence of typhoid ^[69]
	Increased harmful cyanobacterial algal blooms ^[31,32] leading to increased poisonings from fish and shellfish ^[33]	Increased incidence of dermatitis ^[46]
	Increased poisoning due to increased exposure to pathogens and chemicals from agriculture ^[34]	Increased reproductive dysfunction ^[47]
	Lowered birth weight ^[38]	Increased incidence of skin cancer ^[48]
	Increased preterm births ^[80]	Increased occupational pain ^[50]
	Increased urinary tract infections ^[57]	Decrease in cold-related deaths ^[56]

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Western Cape Climate Change and Health Research Questionnaire

Informed Consent to Participate in this Questionnaire

Dear Colleague in Health,

We are a team of climate change and health researchers from the University of Cape Town (UCT), School of Public Health and Family Medicine, Division of Environmental Health. In collaboration with the Western Cape (WC) Government and the Cape Higher Education Consortium (CHEC), we are creating a research database of climate change and health research that:

- a) has previously been conducted and/or
- b) is currently being conducted and/or
- c) is planned to be conducted in the future

We are interested in research conducted in, or on the WC only. The aim is that this database will assist in identifying research gaps, areas for future research and funding needs for future research in climate change and health in the WC. We are also assessing what drives researchers to conduct climate change and health research in the WC, and whether those drivers are in line with meeting the needs of the WC health sector.

Our team members comprise of:

A/Prof Hanna-Andrea Rother (Primary Investigator)
Dr Christie Godsmark (Project Co-ordinator)
Mr Tshepo Phakisi (Master of Public Health Candidate)

We therefore, invite you to participate in this questionnaire which should take approximately 10 minutes to complete.

There are no potentially harmful risks recognised in participating in this questionnaire. There will not be individual benefits of participating in the study. However, the results of the questionnaire will highlight priority areas for the WC health sector.

Your participation is completely voluntary. Refusal to participate in or withdrawal from this study at any time will have no negative effect on you in any way. Your responses will be confidential unless you specifically cite your publications, work or research.

This research has been approved by the University of Cape Town Human Research Ethics Committee (HREC: 299/2017).

The results from this study will inform a report for a Cape Higher Education Consortium project with anonymised data presented in a peer-reviewed publication.

Should you have any questions or would like to request further information at any time during this research, please feel free to contact Dr Christie Godsmark at christie.godsmark@uct.ac.za

* Required

1. **I have read the information above, understand that I can withdraw at any time, and confirm that I am willing to take part in this study. ***

Mark only one oval.

- Yes (this will start the questionnaire)
- No (this will exit the questionnaire) *Stop filling out this form.*

Demographics

Researcher demographics

2. **Salutation ***

Mark only one oval.

- Prof
 Dr
 Mr
 Mrs
 Ms
 Other: _____

3. **First Name**

This is not a required field, but your details would be appreciated for follow-up purposes if necessary.

4. **Last Name**

This is not a required field, but your details would be appreciated for follow-up purposes if necessary.

5. **Email Address**

This is not a required field, but your details would be appreciated for follow-up purposes if necessary.

6. **Gender ***

Mark only one oval.

- Female
 Male
 Prefer not to say
 Other: _____

7. **Institution: ***

8. **Current Position: ***

Research Interest

9. **Climate change and health research on the Western Cape ***

Mark only one oval.

- I have, in the past, researched climate change and health on the Western Cape *Skip to question 10.*
 I am currently researching climate change and health on the Western Cape *Skip to question 10.*
 I have never researched climate change and health on the Western Cape but I am planning to *Skip to question 16.*
 I do not work on climate change and health on the Western Cape *Stop filling out this form.*

Western Cape Climate Change and Health Research

10. Please select the research area(s) that you focus on concerning the Western Cape (choose as many options as needed). Please also consider any student's work that you may be involved with supervising and/or co-authoring.

Check all that apply.

	I have previously researched this topic	I am currently researching this topic
Allergies and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Cancer and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Cardiovascular disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Communicable / infectious disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Death and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Food-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Health benefits of climate change	<input type="checkbox"/>	<input type="checkbox"/>
Heat-related health effects and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Immune function and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Injury and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Mental health and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Musculoskeletal disorders and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Nutrition / malnutrition and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Other chronic diseases and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Other water illnesses and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Poisonings (e.g. pesticides) and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Renal disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Respiratory disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Reproductive health (including sexually transmitted diseases and infections) and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Review of all climate change and health focus areas	<input type="checkbox"/>	<input type="checkbox"/>
The burden of disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Tight/sick building syndrome and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Vector-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Vulnerable populations (e.g. children and the elderly) and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Water-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>

11. If you selected "other", please detail here.

12. Please list all the titles, and provide citation links where possible, for any research you have conducted on climate change and health in the Western Cape.

Supervision of Students

13. Do you supervise postgraduate students focusing on climate change and health in the Western Cape? *

Mark only one oval.

- Yes
 No Skip to question 15.

Supervision of Students

Regarding climate change and health research on the Western Cape

14. Please list the titles and links, where available, of any student theses (within the last 10 years), with their level of study (e.g. PhD or Masters) and year of graduation. *

Future Western Cape Climate Change and Health Research

15. Do you plan on undertaking climate change and health research focusing on the Western Cape in the future? *

Mark only one oval.

- Yes
 No Skip to question 17.

Future Western Cape Climate Change and Health Research

16. Please indicate which topic(s) you plan to focus on. Tick as many areas as required. *

Check all that apply.

- Allergies and climate change
- Cancer and climate change
- Cardiovascular disease and climate change
- Communicable / infectious disease and climate change
- Death and climate change
- Food-borne disease and climate change
- Health benefits of climate change
- Heat-related health effects and climate change
- Immune function and climate change
- Injury and climate change
- Mental health and climate change
- Musculoskeletal disorders and climate change
- Nutrition / malnutrition and climate change
- Other chronic diseases and climate change
- Other water illnesses and climate change
- Poisonings (e.g. pesticides) and climate change
- Renal disease and climate change
- Respiratory disease and climate change
- Reproductive health (including sexually transmitted diseases and infections) and climate change
- Review of all climate change and health focus areas
- The burden of disease and climate change
- Tight/sick building syndrome and climate change
- Vector-borne disease and climate change
- Vulnerable populations (e.g. children and the elderly) and climate change
- Water-borne disease and climate change
- Other: _____

Research Motivations

17. In your opinion, what are the main climate change and health research areas that should be focused on?

Check all that apply.

	Most important research area	Second most important research area	Third most important research area
Allergies and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cancer and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cardiovascular disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Communicable / infectious disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Death and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Food-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Health benefits of climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Heat-related health effects and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Immune function and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Injury and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mental health and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Musculoskeletal disorders and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nutrition / malnutrition and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other chronic diseases and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other water illnesses and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Poisonings (e.g. pesticides) and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Renal disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Respiratory disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reproductive health (including sexually transmitted diseases and infections) and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Review of all climate change and health focus areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The burden of disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tight/sick building syndrome and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vector-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Most important research area	Second most important research area	Third most important research area
Vulnerable populations (e.g. children and the elderly) and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Water-borne disease and climate change	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (if you choose this option, please elaborate in the next question)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

18. If you selected "other" in the previous question, please detail here.

19. What motivates you to research climate change and health in the Western Cape? Tick as many areas as required. *

Check all that apply.

- Funding opportunities
- Community need
- Personal interest
- Student interest
- Faculty priorities
- Job requirement
- Provincial priorities
- Other: _____

20. Please rank your motivations.

Check all that apply.

	Funding opportunities	Community need	Personal interest	Student interest	Faculty priorities	Other	Job requirement	Provincial priorities
Primary Motivation	<input type="checkbox"/>							
Secondary Motivation	<input type="checkbox"/>							
Tertiary Motivation	<input type="checkbox"/>							

21. What organisations/bodies have funded your research? Please indicate if these are local or international.

22. Please let us know if any of your colleagues are either working on, or planning to work on climate change and health research in the Western Cape (names and email):

23. Is there any other information that you feel would be important to mention for the purposes of this questionnaire?

24. Would you like to join our climate change and health e-network list? This list will display your name and email address only and will be available to other climate change and health researchers. *

Mark only one oval.

- Yes
 No *Skip to question 28.*

Climate Change and Health Network

You only need to complete this section if you did not fill in your name, surname and email address in the earlier section.

25. Name

26. Surname

27. Email address

Questionnaire Feedback

28. Do you have time to answer three questionnaire feedback questions? *

Mark only one oval.

Yes

No Stop filling out this form.

Questionnaire Feedback

Thank you for giving us a little more minutes of your time.

29. How easy was it to fill out this questionnaire?

Mark only one oval.

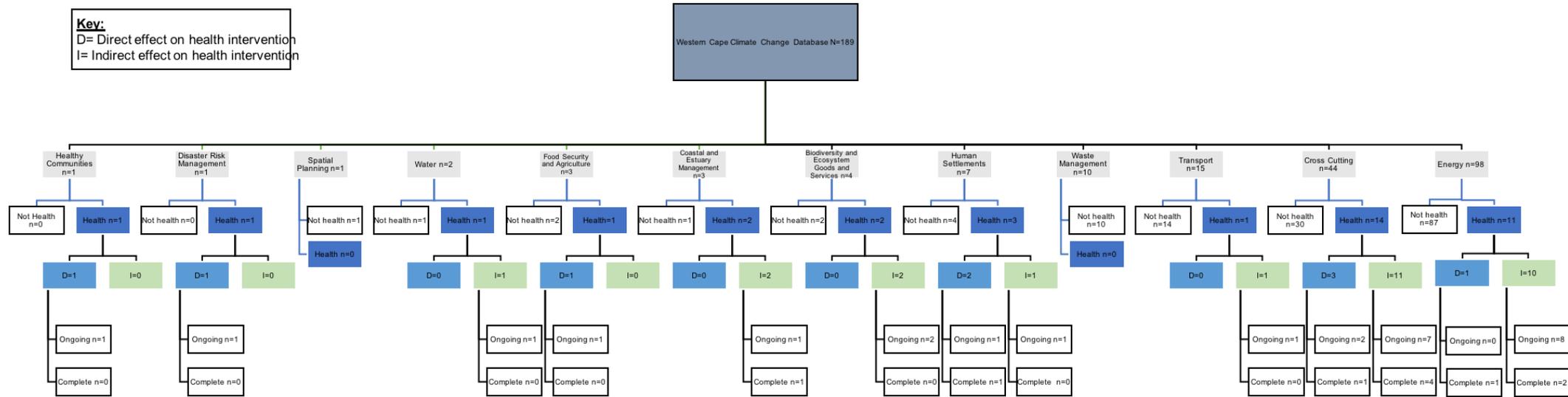
1 2 3 4 5

Not easy at all Very easy

30. Do you have any comments on the design of the questionnaire?

31. Do you have any suggestions as to how the questionnaire could be improved?

Appendix 6: Analysis of the Western Cape climate change database



Direct Impact on Health

City of Cape Town Climate Adaptation Plan of Action: Health
City of Cape Town Climate Adaptation Plan of Action: Disaster Risk Management
The Smart Agriculture for Climate Resilience (SmartAgri)
Stepping up to Sustainability
Mamre Ceilings Pilot Project
City of Cape Town N2 Gateway Housing Development
Western Cape Green is Smart Green Economy Strategy Framework
Working on Fire
City of Cape Town Kuyasa EE Pilot Project

Indirect Impact on Health

City of Cape Town Climate Adaptation Plan of Action- Catchments, Rivers, and Storm water
City of Cape Town EE Street and Traffic Lights Program
Working for Ecosystems
City of Cape Town Smart Living Campaign
Jobs for Carbon Project
City of Cape Town Climate Adaptation Plan of Action- Coastal
City of Cape Town Ceilings Roll-out
Hessequa External Awareness Raising
Working for Wetlands
Fruitlook
Overberg Climate Change Response Framework
City of Cape Town Electricity Saving Campaign
City of Cape Town Electricity Behavior Change with Automatic Meter Readings
GreenPop Reforestation Projects
City of Cape Town Residential Solar Water Heater Programme
Drakenstein Solar Water Heater Programme
Project 90x2030 EE Demonstration Sites Project
Earth Hour City Challenge
Stellenbosch Non-Motorized Transport Network Plan
Working for Water
Drakenstein Smart Metering Pilot
GEF Fynbos Fire Project
Sea Level Risk and Flood Assessment for Select Disaster Prone Areas Along the Western Cape
Cape Town Low-Carbon Central City Strategy
Western Cape Government Energy Efficient Aids for Low Income Households
Increasing Investment in Climate Change Related Projects at the Sub National Level
2010 FIFA World Cup Green Goal Action Plan
Private Sector Energy Efficiency (PSEE)

Appendix 8: Key Western Cape climate change documents

Cartwright, A. (2008). Global Climate Change and Adaptation - A Sea-Level Rise Risk Assessment. Stockholm Environment Institute. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

CNdV Africa Planning and Design (2006). Strategic Initiative to Introduce Commercial Land Based Wind Energy Development to the Western Cape. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Midgley, G.F., Chapman, R.A., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheibir, P., Forsyth, G.G. (2005). A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate Change in the Western Cape. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Western Cape Government (2013). Green is Smart - Western Cape Green Economy Strategy Framework. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Department of Environmental Affairs and Development Planning, Western Cape Government (2008). A Climate Change Strategy and Action Plan for the Western Cape. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Department of Environmental Affairs and Development Planning, Western Cape Government (2012). Western Cape Energy Consumption and CO₂e Emissions Summary Report. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Department of Environmental Affairs and Development Planning, Western Cape Government (2014). Western Cape Climate Change Response Strategy. Available at: <https://www.westerncape.gov.za/eadp> (Accessed: 16 March 2018).

Department of Environmental Affairs and Development Planning, Western Cape Government (2016). Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16. Available at: <https://www.westerncape.gov.za/eadp/sites/eadp> (Accessed: 16 March 2018).

Appendix 9: Additional climate change interventions of projects in the Western Cape

Title	Type	Description	Source	Date
Facing the Heat: Barriers to Mainstreaming Climate Change Adaptation in Local Government in the Western Cape Province, South Africa	Scholarly article	Case-study on barriers to climate change adaptation in the WC through interviews with 47 municipal actors on their experience with climate impacts and adaptive actions.	(Pasquini et al., 2013, <i>Habitat International</i>)	2013
Developing a Municipal Adaptation Plan (MAP) for Climate Change: The City of Cape Town	Scholarly article	Framework for municipal-scale adaptation plan for Cape Town with adaptation intervention methods for various hazards.	(Mukheibir & Ziervogel, 2007, <i>Environment & Urbanization</i>)	April 2007
Can Preparing for Climate Change Have Social Benefits?	Conference	The department of design was a three-week conference that provided various speakers, workshops and activities to brainstorm ideas to adapt to climate change in Cape Town- one particular adaptation strategy mentioned visual gaming for climate awareness and action (Tygron visual web design).	(Deppa, 2014, <i>Future Cape Town</i>)	July 28, 2014
Western Cape Government Health Climate Change Committee	Committee	Brainstorm of how 'WCG: Health' can reduce its contribution to climate change (mitigation) and prepare for inevitable change (adaptation) with a focus on energy and emissions reduction strategies.	Western Cape: Department of Health	Established 2016
Towards Day-to-Day Resilience: A Policy Framework for Climate Change Response in the West Coast District	Climate change response framework	Climate change projections and responses with risk summaries for given districts on the West Coast using mitigation and adaptation strategies. This framework vaguely mentions health.	West Coast District Municipality	Sept 2014
Climate Change Science: The Literacy of Geography Teachers in the Western Cape Province, South Africa	Case-study	A case study completed to assess high school geography teachers level of knowledge about climate change to better understand how the curriculum around it is being taught to students. The results showed that although majority of participants understood climate processes and causes, there was a lack of understanding of climate change impacts and solutions. Findings showed development program/interventions in teacher knowledge would enhance education on climate change in schools.	(Anyanwu et al., 2015, <i>South African Journal of Education</i>)	Aug 2015
Climate Adaptation Readiness for Agriculture:	Policy brief of a case-study	A case study that assesses whether government-led resilience building initiatives have mitigated the 2015/2016 drought. This was done to discern key weaknesses and opportunities exposed by the drought to	South African Institute of International Affairs	Nov 2016

Drought lessons from the Western Cape, South Africa		draw outcomes for a smarter plan through a two-day provincial multi-stakeholder drought dialogue.		
Eden District Municipality Climate Change Adaptation Plan	Climate change adaptation plan	Eden Districts climate change approach using adaptation and mitigation strategies. Projects are listed according to climate change risk and include health.	Eden District Municipality	Feb 2010
Reconciliation Strategy for the Western Cape Water Supply	Strategy for water preservation	The strategy objectives are to reconcile future water requirements with supply for a 25-year planning horizon and to provide a framework for decision-making with regard to both securing water supply and managing demand.	Western Cape Water Supply System: Department of Water and Sanitation	2015
Update on Renewable Energy Developments in the Western Cape	Specialist group	The Bird and Wind Energy specialist group is comprised of specialists who guide 'Birdlife South Africa' towards minimizing the impact of wind energy on birds and have been identified as a key stakeholder in the roll out of renewable energy developments, providing advice to government, industry and environmental consultants.	Cape Town Birding	Nov 2014
The Green Connection	Climate change communication project	Climate change communication projects in local communities in the Karoo with little to no knowledge on climate change to improve awareness and build capacity. In 2012/2013, the Western Cape Government requested help from the Green Connection in approaching climate change awareness for citizens of the WC.	Green Connection	2012
Provincial Drought Update and Impacts	WCG drought response document	Update on current drought situation, impact on economy, day zero, and WCG response to drought disaster.	Western Cape Government	Dec 2017
The Role of Behavioural Interventions in Climate Change Adaptation and Mitigation	Website	This project aims to use low-cost and scalable behavioural-economic interventions to facilitate pro-environmental behavioural change in the Western Cape of South Africa. Specifically, the objective is to induce a reduction in electricity and water consumption across a large sample of residential homes.	Environment for Development	2015
Water Resource Infrastructure Implications of a Green Economy in Transition in the Western Cape Province Cape Town South Africa: A System Dynamics Approach	Scholarly Article	The research summarizes the factors that relate to water resources and influence the transition to a green economy in the Western Cape Province. Subsequently, a system dynamics model was developed to evaluate the impact of key strategic interventions of the green economy transition. The results from the model show that the Province could possibly experience extreme water shortages in the near future if a business-as-usual scenario continues.	(Piennar, 2016, <i>South African Journal of Industrial Engineering</i>)	Aug 2017

Western Cape Water Crisis- How Resilient is Your Organization in the Face of the Current Water Crisis?	Public document on a business resilience approach	Risk management approach for businesses to utilize during the water crisis to help remain in business in the Western Cape.	Price Waterhouse Cooper	Dec 2017
Air Quality Management Plan for the Western Cape	Government management plan	Approach for air pollution control in the Western Cape that is in line with international policy development and environment rights.	Department of Environmental Affairs and Development Planning	2010
Western Cape Provincial Workshop CDM Awareness Raising Campaign	Campaign	Energy consumption awareness-approach based around climate change impacts and energy efficiency.	Energy and Climate Change Department	2011
A Grassroots Women's Initiative to Climate Change Resilience	Initiative	Khulisa conducted a baseline study on the sustainable use of natural resources to improve climate change resilience amongst 350 women in eight South African communities	Khulisa Management Services	June 2017
Commercial fishing and Aquaculture Implications of a Green Economy Transition in the Western Cape	Scholarly article	This article concludes that system dynamics modelling is an appropriate tool for determining the influence of both climate change and government intervention on fisheries and aquaculture in the Western Cape. It is recommended to construct a system dynamics model with the overall modelling goal of evaluating proposed provincial governmental frameworks and action plans in terms of social, economic and environmental sustainability, taking into account the anticipated future climate change in the Province.	(Duminy et al., 2015, <i>International Association for Management of technology</i>)	2015
The Better Living Challenge	Framework	A series of challenges that aim to surface design innovations that support the improvement of living conditions of low-income communities over a 5-year period.	The Better Living Challenge	Oct 2017
State of Environment Outlook Report for the Western Cape Province	Government report	Update on drivers, pressures, energy and land use, transportation, agriculture etc. on projected climate change events and how that will impact various sectors appropriate and updated responses.	Western Cape Government	November 2017
Cape Town Adaptation Handbook	Handbook	Handbook that places emphasis on three key concepts: interconnectivity, continuity and local relevance. Interconnectivity refers to how the different climatic impacts and the associated adaptation options are connected. Through addressing one particular impact or implementing one adaptation option, there are generally 'knock-on' effects affecting a multitude of people, sectors and economies (the	Local Governments for Sustainability	2012

		ripple effect). Climate change responses must change as the climate itself does.		
Institutional Pathways for Local Climate Change Adaptation: A Comparison of Three South African Municipalities	Case-study comparison report	The research focused on the factors enabling and constraining climate change adaptation in three South African municipalities. Cape Town, Durban and Theewaterskloof are perceived to be local leaders in adapting to changing climate conditions and how the political, institutional and social factors shape the initiation of climate adaptation at the municipal scale.	Focales	March 2014
Provincial Climate Change Summary	Toolkit for climate change response	Summary of vulnerabilities, projections, and responses that the Western Cape Province can take in terms of mitigation and adaptation options based off of the provincial vulnerabilities.	Let's Respond	2014

Appendix 10: Examples of national interventions or projects addressing climate change-related health outcomes

Projected Health Outcome	Type	Description	Mentions Climate Change (Y/N)	Source	Date
Heat-related deaths and illnesses	Adaptation plan	National Climate Change and Health Adaptation Plan. Document outlines long term goals such as developing a dialogue with Department of Labour (DOL) and employers, designing a comprehensive communication strategy and developing sources of accessible information on climate change and health to raise public awareness and coping ability to climate change impacts.	Y	(Department of Health, 2014)	2014-2019
	Scholarly article	High Occupational Temperature Health and Productivity Suppression (HOTHAPS). A program to quantify the extent to which people are affected by and adapt to heat exposure. The study concluded that few, if any, measures are being undertaken to protect worker health or improve worker comfort.	Y	(Mathee et al., 2010, Global Health Action)	2010
	Adaptation scenarios	Long Term Adaptation Scenarios. A two-phase vulnerability assessment (DOH and WHO) of the health sector in South Africa to determine heat health impacts from climate change and adaptation measures to be taken (i.e. developing a heat-health action plan which has not be started).	Y	(Department of Environmental Affairs, 2013)	2018
	Dataset analysis	The Association Between Ambient Temperature and Morality in South Africa: A Time-series Analysis. Search of temperature-mortality and associations in South Africa to understand the mortality burden that is associated with cold and heat.	Y	(Scovronick et al., 2018, Environmental Research)	2018
	Risk assessment	Sub-Saharan African Cities: A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action. Risk assessment to shape adaptation framework that predicts that increased frequency of heat waves will impact on public transport and therefore livelihoods, having health effects such as dehydration, sunstroke, and accidents.	Y	(Roswell & Fairhurst, 2011, Local Governments for Sustainability)	2011
Cardiovascular disease	Strategic plan	Strategic Plan for the Prevention and Control of Non-Communicable Diseases. The document suggests development of hypertension drug treatment programs, adequate referral systems, continuum of care, and the development of detailed human resource strategies to reduce cardiovascular disease through relatively low-cost methods.	N	(Ministry of Health, 2013)	2013-2017

	Plan of action	National Plan of Action for Children in South Africa 2012-2017. Proposal from the planning commission encouraging compulsory physical education in all schools by 2020 to instill culture of health lifestyle behavior.	Y	(Department of Women, Children and People with Disabilities, 2012)	2012-2017
	Strategic plan	Strategic Plan 2014/15- 2018/19. Call for further health promotion and nutrition interventions to engage whole population in healthy eating habits, physical exercise, and responsible lifestyles.	Y	(Department of Health, 2014)	2014/2015-2017/2018
	Scholarly article	A Hidden Menace: Cardiovascular Disease in South Africa. Treatment guidelines (STGs) and Essential Drug List (EDL) implemented through the Department of Health to get treatment and management of cardiovascular disease to poorer communities.	N	(Maredza et al., 2011, Journal of South African Heart Association)	2011
Respiratory disease	Strategic plan	Strategic Plan for the Prevention and Control of Non-Communicable Diseases. Reduce tobacco use through mass media campaigns, worksite interventions, and fiscal measures such as taxes on tobacco products, smoke free workplaces, packaging/labeling measures. Inhaled corticosteroids for asthma roll out, coupled with educational campaigns.	N	(Ministry of Health, 2013)	2013-2017
Renal disease	Strategic plan	Strategic Plan for the Prevention and Control of Non-Communicable Diseases. Educational campaign for lifestyle changes that aim to reduce risk factors such as poor diet, smoking, physical inactivity and alcohol consumption.	N	(Ministry of Health, 2013)	2013-2017
Vector-borne diseases	Adaptation plan	National Climate Change and Health Adaptation Plan. Rodent infestation prevention through universal service delivery and ensuring the integrity of sewerage systems, efficient waste disposal services and domestic hygiene. Capacity building for the sound management of public health-risk related to climate change through the training of national experts and environmental health fraternity on various climate change and health areas.	Y	(Department of Health, 2014)	2014-2019
	Regional training	Investing in Prevention for Better Management and Control of Vector-borne Disease Outbreak. A Five-day training involving health and disaster management managers from ten African National Red Cross and Red Crescent Societies, as well as International Federation of Red Cross health and disaster management specialists.	Y	(International Federation of Red Cross and Red Crescent Societies, 2016)	2016

	Control measures	Malaria Outbreak in South Africa. Control measures including indoor residual spraying, mop up spraying, and public awareness on malaria prevention, case management in health facilities, and how malaria impacts on health.	N	(Department of Health, 2017)	2017
Mental ill health	Framework and strategic plan	National Mental Health Policy Framework and Strategic Plan. Addresses mental health factors including epidemiology, costs, determinants of health, prevention, treatment, rehabilitation, service provision, and policy/legislation. Policy development through the creation of ministerial mental health advisory committee by the National Department of Health in 2015. Policy guidelines on 72-hour assessment of involuntary mental health care users following the Bill of Rights and based off of human rights. It provides specific procedural protection for a person involuntarily committed to care, treatment or rehabilitation.	N	(Department of Health, 2013)	2013-2020
Hazard specific deaths/injuries	Risk assessment study	The High Burden of Injuries in South Africa. First study to describe the magnitude and impact of injury-related burden in South Africa. The global burden of disease methodology was used to estimate the injury burden from a range of injury data in South Africa to shape response strategies.	N	(Norman et al., 2007, Bulletin of the World Health Organization)	2007
	Risk assessment study	Paraffin-related Injury in Low-income South African Communities. Study in South Africa that conducted home inspections and perceived risks of paraffin-related injuries needed for educational interventions. The study concluded that policymakers should develop strategies to educate citizens on the risk of paraffin through curricula, programmes mass media outlets and communal participation.	N	(Schwebel et al., 2009, Bulletin of the World Health Organization)	2009
	Risk assessment	National Veldfire Risk Assessment. Outlines the climate change impacts and the increased likelihood of wildfires and injuries that will result. The document aims to improve current risk management approach.	Y	(Forsyth et al., 2010, CSIR)	2010
	Strategic plan	Strategic Plan 2014/15- 2018/19. Department of Health coordinated disease/injury surveillance and research through the establishment of a National Public Health Institute of South Africa (NAPHISA)	Y	(Department of Health, 2014)	2014/15-2018/19
	Health and safety act	Occupational Health and Safety Act of 1993. Promotes safety/minimizes harm and injury in the work place.	N	(Department of Labour, 1993)	1993
Malnutrition	Program	National Plan of Action for Children in South Africa 2012-2017. School nutrition program that reached six out of ten children in public schools between 1994-2005.	Y	(Department of Women, Children and People with Disabilities, 2012)	2012-2017

	Roadmap	National Plan of Action for Children in South Africa 2012-2017. Roadmap on nutrition for South Africa that outlines a plan for managers, supervisors, government departments, development partners, and health care personnel to guide towards optimal nutrition for all people in South Africa.	Y	(Department of Women, Children and People with Disabilities, 2012)	2013-2017
	Guidelines	Implementation Guidelines for Nutrition Interventions at Health Facilities to Manage and Prevent Malnutrition. Promotes communal understanding of nutritional disorders and to ensure consistent optimal nutrition service delivery to all clients.	N	(Department of Health, 2013)	2013
Infectious diseases	Framework	Antimicrobial Resistance National Strategy Framework. The framework for the antimicrobial resistance strategy and the antimicrobial stewardship toolkit for managing antimicrobial resistance and limited further increased resistant microbial infections to improve patient outcomes.	N	(Department of Health, 2014)	2014-2024
	Elimination plan	Malaria Control Program. An elimination plan aimed to strengthen passive and active surveillance and monitoring and evaluation systems and ensure that the program has the capacity to operate correctly by to supplying the public with information on how to prevent the spread of malaria.	N	(Department of Health, 2012)	2012-2018
Water-borne diseases	Guidelines	Guidelines for the Management of Waterborne Epidemics. Promotes coordinated management of outbreaks of waterborne diseases through protocol procedure (with the emphasis on cholera).	N	(Department of Water Affairs and Forestry, 2002)	2002
Allergies	Guidelines	Standard Treatment Guidelines and Essential Medicines List for South Africa. Guidelines for essential medicine in allergic reactions and a guide to patient education in chronic diseases.	N	(Department of Health, 2015)	2015

Appendix 11: Global interventions or projects addressing climate change-related health outcomes

Projected Climate Change-Related Adverse Health Impact	Examples of Global Intervention Projects
Heat-related deaths and illnesses	<p>The Green Curtains project has spread across 80% of various industries in Japan and has shown that covering the outer facades of buildings with living edible vegetation has “lowered indoor temperatures naturally, in turn minimizing the use of air conditioners, while promoting healthy diets, cleaner air, and improved wellbeing all while saving energy and reducing pollution through sequestered carbon emissions” (Kyocera, 2018).</p>
Cardiovascular diseases	<p>The NHS Health Check is a program being utilized in England for the prevention and early detection of cardiovascular disease (Gov.UK, 2018). The program uses a systematic approach to measure a range of risk factors for CVD (and other diseases) and offers the patient a personal risk profile and follows with early identification of vulnerable high-risk individuals and previously undiagnosed high-risk conditions (Gov.Uk, 2018). The program has found that treating blood pressure and cholesterol alone could greatly reduce annual cases of CVD and the program refers individuals to lifestyle management services to motivate individuals to take action to reduce main risk factors going forward (Gov.UK, 2018).</p> <p>The Healthy Streets for London is a project that launched in 2017 and aims to make “communities greener, healthier, and more attractive” by implementing walking and cycling space into the cities Transport Strategy with public health in mind” (Transport for London, 2017). The project aims to replace short car trips with bicycling or walking, hoping to reduce CO₂ emissions by 60%, while increasing the amount of citizens getting exercise each day (Transport for London, 2017). The initiative projects that if “Londoners walk or cycle for at least 20 minutes per day that various reductions in health outcomes will occur, including 16,400 fewer cases of cardiovascular disease” (Transport for London, 2017).</p>
Mental ill-health	<p>Mental Health and Our Changing Environment was a document published by the American Psychological Association that provides tangible guidance, actions, and steps that individuals, communities, and organizations can take to prepare for climate-related mental health outcomes. Such steps include having an emergency plan in place, a social support system, and understanding individual medical needs before disasters occur (Mental Health and Our Changing Environment, 2017).</p>
Hypothermia	<p>“The California State Water Project manages levees and other flood protection structures, develops the State’s strategic plan for water resources, administers over USD\$1b in grant funds for improvements to local water resources, and oversees dam safety throughout California” (Climate Leadership Conference, 2018).</p>
Reduced water quality resulting in diseases	<p>Green infrastructure (rooftop greening, rain barrels, permeable pavements and tree cover) is utilized to manage storm water during current and future periods of heavy precipitation. This aims to decrease the risk of sewer overflow and prevent water contamination during periods of high precipitation (Green Infrastructure, USA, 2015).</p>
Allergies	<p>The Asthma and Allergy Foundation of America is an advocacy group that provides educational awareness on the dangers of climate change and respiratory effects. The group provides insight into allergy triggers, allergy warning signs and symptoms, at risk groups for allergic reactions, allergy friendly products, as well as advocates for the Clean Air Protection Initiatives and the continuation of the National Asthma Control Program (Asthma and Allergy Foundation of America, 2018).</p>

Social conflicts	Saferworld, an NGO has done field research in Kenya and Bangladesh to better understand the relationship between social conflict and climate change. Saferworld developed contextual scenario-based planning approaches to social conflict and climate change in Nepal, a climate sensitive and violence prone country. The NGO incorporated the community's participation into the creation and development of a local adaptation plan of action through awareness raising workshops and analysis of potential local conflict situations. Stakeholders and community participation were vital for uptake of the intervention and increased awareness of the link between social conflict and climate change (Saferworld, 2011).
Hazard-specific death and injuries (burns)	SunSmart in Australia has implemented country wide educational awareness programs to promote protective measures and reduce UV exposure since temperature increase (linked to climate change) plays a role in the UV index and resulting sunburns as well as behavioural changes as people spend more time outdoors in warmer weather. The program has used a multi-strategy communications program to consistently get the message of the importance of sun safety across to various parts of the population hoping to "improve skin cancer prevention awareness, knowledge, attitudes and behaviour in priority populations, support priority populations to detect skin cancers earlier, and advocate for measures that aim to reduce the health and economic burdens of skin cancer" (SunSmart, 2018).
Renal disease	Climate change induced temperature increase and chronic heat stress and dehydration from strenuous agricultural work has caused renal failure to become a major issue in areas of Central America and elsewhere across the globe. The Water.Rest.Shade (WRS) programme is an intervention that implemented the provision of water to individuals through backpacks, mobile shade and rest stations, and ergonomically improved machetes to reduce worker energy expenditure. The intervention found that symptoms associated with renal disease (dehydration and heat stress) drastically improved and that the health of sugar cane workers improved (Bodin et al., 2016).
Vector-borne diseases	In Quebec, efforts to understand the local vector ecology and patterns of disease in relation to climate change have been undertaken. For example, in 2014-2015, the Quebec Ministry of Health and Social Services (MHSS) acknowledged that distribution of vector borne diseases would change with climate change and intervened when rates of Lyme disease were increasing. The MHSS created a province-wide communications project that distributed health information to outdoor enthusiasts and people living in affected areas about the "risk, preventative measures, and early symptoms that should be seen by a health professional". Additionally, the MHSS provided "physicians with detailed explanations about the risk of Lyme disease following a tick bite, ways to improve diagnosis and the tools available to guide post-exposure prophylaxis" (Lowe, 2016).

Appendix 12: Global examples of programmes addressing environmental health risk factors exacerbated by climate change for the Western Cape Government to review

Projected Climate Change-Related Adverse Health Impact	Examples of Global Intervention Projects
Respiratory diseases	ProAire is a program running in Mexico City that is based around 116 actions aimed to “improve air quality and reduce ozone concentrations, greenhouse gas emissions, and health risks from air contaminants (ProAire, 2018). By taking actionable measures, Mexico has seen drastic improvements in air quality and CO2 emissions over the last 25 years through improvements in fuel quality, a no-driving-day program, subway and a bike-sharing expansion, and modernizing air monitoring systems” (ProAire, 2018).
Malnutrition	Espigoladors Cleaning Movement is a social enterprise that reduces food waste and simultaneously creates equitable job opportunities for people at risk of socio-economic exclusion through the recuperation of aesthetically unappealing fruits and vegetables into sauces and various products that promote healthy eating habits and reduce food waste. From a health perspective, the initiative combats food insecurity (especially for marginalized populations), promotes healthful eating, and combats malnutrition. From a climate change perspective, the initiative conserves millions of litres of water, while significantly minimizing CO ₂ emissions, “reducing land pressure and emissions from agriculture, as well as reducing methane emissions from landfills ” (Espigoladors, 2018)
Infectious diseases	“Partners in Health” acknowledges the link between climate change-related air pollution and tuberculosis transmission. The organization “supports community treatment programs and helps families pay to build an additional room to house the infected patient, thereby reducing the risk of crowding, while also supplying clean fuels such as kerosene to reduce indoor air pollution” (Schmidt, 2008).