05 Climate change and health

5.1 Climate change-related health impacts in South Africa: preparing the health sector and calling for indicators to measure and prevent adverse effects

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Introduction

Climate change is considered one of the greatest threats to human health and well-being globally[1] and in South Africa, where growing evidence suggests that these threats most affect vulnerable and lower-income populations.[2] As greenhouse gas (GHG) emissions continue to drive rising global surface temperatures and erratic weather patterns, low- and middle-income countries (LMICs) remain disproportionately affected by climate change, while having the least adaptive capacity to prevent adverse impacts.[3]

Extreme weather events, such as frequent and intense heat waves, lead to heat-related illnesses and deaths, injuries, and displacement, among others.[4] Prolonged droughts deplete water supplies, leading to dehydration, food insecurity, and malnutrition, particularly in already vulnerable populations.[5] Floods and storms contribute to the spread of communicable diseases and create long-term mental health challenges for affected communities. Increased flooding combined with warmer temperatures expand the habitats of mosquitoes and ticks, leading to a heightened prevalence of vector-borne diseases such as malaria, dengue fever, and Lyme disease.[6] The combination of these direct and indirect health impacts underscores the complex relationship between climate change and public health.

In general, LMICs contribute the least to global GHG emissions, so mitigating GHG emissions and transitioning to renewable energy requires a global effort to be effective. Adaptation to climate change impacts is more pertinent to LMICs where evidence-based early warning systems and public health interventions to build community resilience are urgently needed. South Africa needs to focus on a multi-sectoral approach in order to improve human health in the midst of an escalating climate crisis. This chapter aims to present an update on the available evidence, together with the gaps, and the potential for a practical evidence base of climate change-related impacts on human health and well-being in South Africa to inform decision- and policy-making in the health sector.

The chapter provides insights to strengthen and guide climate and health policy and action toward climate-resilient health systems. While the chapter is relevant to a wide audience, it is particularly useful to health policymakers and managers who need support to better understand the impact of climate change on health in South Africa. Health service delivery and health-related infrastructure within the health system that will benefit from resilience-building and adaptive capacity practices are identified. Finally, the chapter calls for the development and implementation of climate change-related health indicators for South Africa to ensure that the health of the country's population is monitored and the risks that climate change poses are understood.

1 Romanello M, Napoli C di, Green C, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. Lancet. 2023;402(10419):2346–94. URL: https://doi.org/10.1016/S0140-6736(23)01859-7
2 Wright CY, Norval M, Albers PN. (2015). Climate change, public health and COP21 – a South African perspective. S Afr Med J. 105(12):997. URL: https://doi.org/10.7196/SAMJ.2015.v105i12.10232
3 Chancel L, Bothe P, Voituriez T. Climate Inequality Report 2023. World Inequality Lab Study 2023/1. Creative Commons Licence CC BY 4.0; 2023.
4 Miller KA, Mcunu N, Anhäuser A, Farrow A, Santillo D, Johnston P. Weathering the storm. Extreme weather events and climate change in Africa. Greenpeace Research Laboratories Technical Report; 2020.
5 FAO, IFAD, UNICEF, WFP, WHO. The state of food security and nutrition in the world 2023. Urbanisation, agrifood systems transformation and healthy diets across the rural–urban continuum. 2023; URL: https://doi.org/10.4060/cc3017en
6 Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Ann NY Acad Sci. 2019;1436(1):157–173. URL: https://doi.org/10.1111/nyas.13950

Overview of climate change and health impacts in South Africa

The Intergovernmental Panel on Climate Change (IPCC 2021) Assessment Synthesis Report 6 (AR6) highlights significant direct health impacts due to climate change, primarily driven by chronic exposure to abnormal weather elements, for example, heat, air pollution, etc., and by extreme weather events including heat waves, floods, and droughts. The increasing frequency, intensity, and duration of heatwaves result in heat-related illnesses and deaths. Floods and storms lead to injuries, drowning, displacement, the spread of communicable diseases, and subsequent mental health issues. Thus, extreme weather events not only cause immediate harm and disrupt livelihoods, but also have long-term health implications in affected populations.

Indirect health impacts are also a major concern. Climate change affects food security and nutrition by disrupting crop yields and reducing the quantity and nutritional quality of food.[7] This leads to food shortages and increased malnutrition, particularly in vulnerable regions. Water scarcity, driven by altered precipitation patterns and increased evaporation, exacerbates health issues by limiting access to clean and safe water.[8] Furthermore, warmer temperatures and increased flooding enhance the spread of infectious diseases. These indirect impacts highlight the intricate link between climate change and various aspects of public health.

Vulnerable populations are disproportionately affected by climate change. Due to geographic and socioeconomic factors, certain regions such as low-lying coastal areas and small island developing states, as well as informal urban settlements that are densely populated and have poor vegetation cover (urban heat islands), are at greater risk for extreme heat exposure. Moreover, children, the elderly, pregnant women, and individuals with pre-existing health conditions are at increased risk due to their physiological and social vulnerabilities.[9] Addressing these challenges requires improving awareness, strengthening community and health systems, developing early warning systems for natural disasters and extreme weather events, and implementing public health interventions to promote resilience. Mitigation efforts, such as reducing GHG emissions and transitioning to renewable energy sources, are crucial in addressing the root cause of climate change to limit future health impacts. The IPCC AR6 underscores the urgency of comprehensive multi-sectoral actions to protect global health in the face of climate change.

Given the immense burden that climate change and extreme weather events are placing on South Africa's health system, the overall scope and calibre of climate resilience research on health and within the health sector seems insufficient.[10] In addition, it is difficult to gauge the effectiveness of adaptation measures in the population, and ongoing efforts are required to ensure that adaptation strategies are effective.[11] Research on extreme weather events, which include extreme heat, wildfires, storms, droughts, and flooding, is a priority to inform strategies for disaster management and early warning systems.[12] Studies focusing on the effects of climatic conditions on the rising prevalence of infectious diseases in South Africa must be prioritised.[13] The challenge of air pollution and how it interacts with climate change impacts, especially in light of its link with detrimental health outcomes and the impacts of poor air quality in low-income communities, must remain a key area of research.[14,15] Figure 1 illustrates the climate change-related factors influencing health and health outcomes in South Africa. In recent years, the health impacts associated with climate change and extreme weather events have been experienced across South Africa. Figure 2 shows some of these specific impacts and events in different regions of the country. Urbanisation in South Africa is growing, and the urban heat island effect must be avoided, as such, city planners should prioritise cooling strategies, urban green strategies, and green building designs. Moreover, low-income communities are less likely to find practical strategies to adapt to extreme heat. For example, the building design and materials used for low-cost housing and schools located in low-income or rural areas are presently inadequate for protecting citizens from extreme heat.

7 Amondo EI, Nshakira-Rukundo E, Mirzabaev A. The effect of extreme weather events on child nutrition and health. Food Secur. 2023;15(3):571–596. URL: https://doi.org/10.1007/s12571-023-01354-8
8 United Nations. Water – at the center of the climate crisis. 2024. URL:https://www.un.org/en/climatechange/science/climate-issues/water
9 Ramathuba M. (2022). National Heat Health Action Guidelines. Guide to extreme heat planning in South Africa for the human health sector. 2022. URL: https://www.health.gov.za/wp-content/uploads/2022/06/National-Heat-Health-Action-Guidelines.pdf
10 Chersich MF, Wright CY. Climate change adaptation in South Africa: a case study on the role of the health sector. Global Health. 2019;15(1):22. URL: https://doi.org/10.1186/s12992-019-0466-x
11 Stadelmann M, Michaelowa A, Butzengeiger-Geyer S, Köhler M. Universal metrics to compare the effectiveness of climate change adaptation projects. In: Handbook of climate change adaptation. Berlin Heidelberg: Springer, 2015; p.2143-2160. URL: https://doi.org/10.1007/978-3-642-38670-1_128
12 Davis-Reddy, CL, Vincent K. Climate risk and vulnerability: A handbook for Southern Africa. 2nd ed. Pretoria: CSIR, 2017.
13 Liao H, Lyon CJ, Ying B,Hu T. (2024). Climate change, its impact on emerging infectious diseases and new technologies to combat the challenge. Emerg Microbes Infect. 2024;13(1). URL: https://doi.org/10.1080/22221751.2024.2356143
14 Shezi B, Wright CY. Household air pollution exposure and respiratory health outcomes: a narrative review update of the South African epidemiological evidence. Clean Air Journal. 2018. URL: https://doi.org/10.17159/2410-972X/2018/v28n1a11
15 Roomaney RA, Cairncross E, Tesfaye M, et al. Estimating the burden of disease attributable to ambient air pollution (ambient PM2.5 and ambient ozone) in South Africa for 2000, 2006 and 2012. S Afr Med J. 2022;112(8B):705–717. URL: https://doi.org/10.7196/SAMJ.2022.v112i8b.16483

Figure 1 Climate change-related drivers and associated health impacts in South Africa

Source: South African Medical Research Council

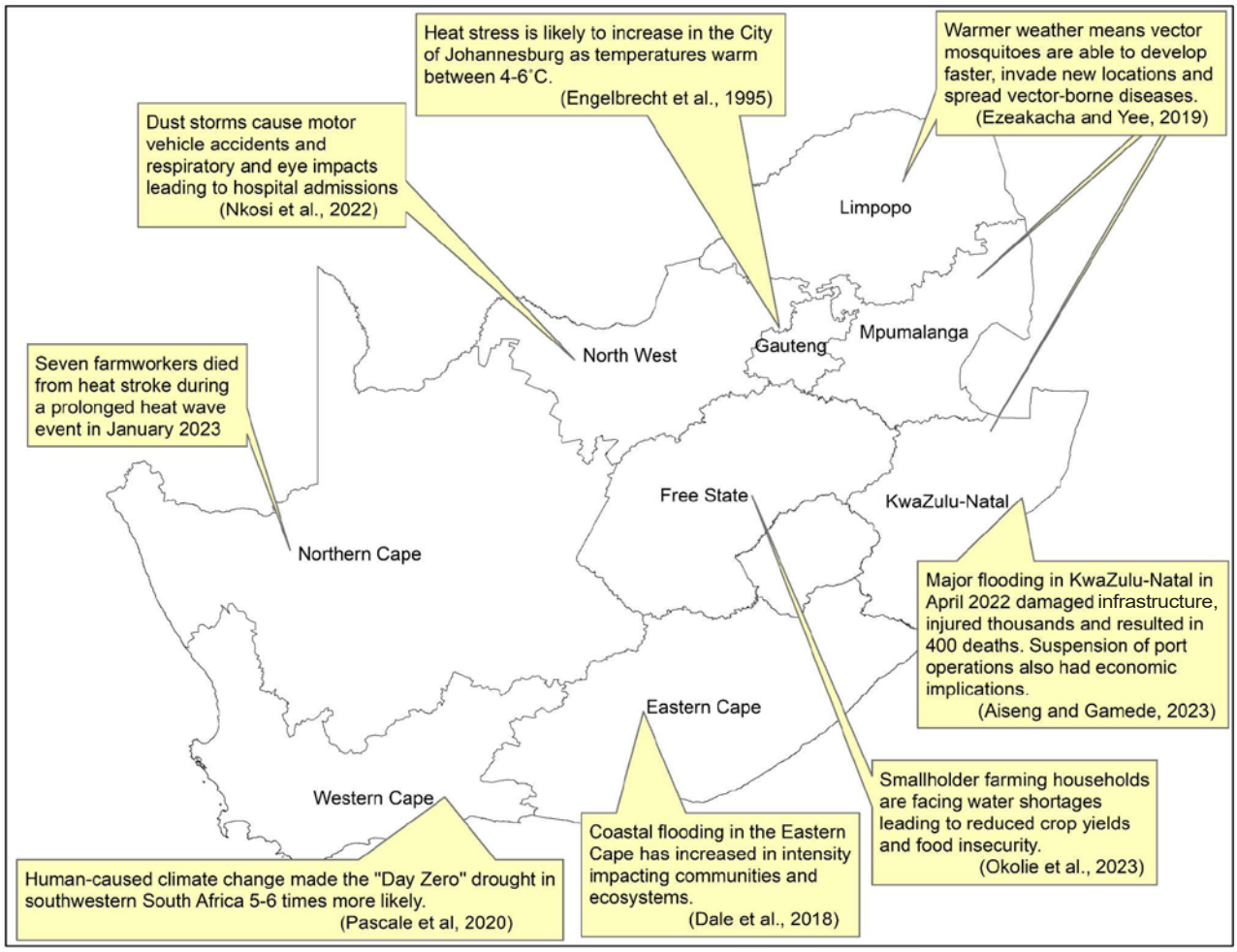

Figure 2 Illustrative examples of climate change and extreme weather events and their health impacts around South Africa

A study in South African district municipalities showed that high temperatures (>32ºC) are statistically significant predictors of all-cause mortality.[16] In addition, there is a strong association between heat-related deaths and regional climate patterns, with threshold variations across the country's climate zones. The hot, arid provinces of the Northern Cape and North West have some of the highest heat thresholds, compared to districts in the temperate interior (mountains) or coastal regions. As population exposure to heat rises, evidence-based heat-health warning systems (HHWS) are essential to reduce heat-related mortality and morbidity. The implementation of heat alerts as part of comprehensive heat-health action plans is critical for public safety. Even with the characterisation of thermal comfort thresholds, working with stakeholders proved to be crucial to developing a HHWS in Rustenburg.[17] In that study, thermal comfort indicators were categorised into colour codes with three being characterised as critical risk (red), twenty-eight as medium-high risk (yellow), and six as low risk (green) in the Rustenburg municipality. Using that categorisation, researchers were able to advise communities on short-term actions, and partnerships between local government and communities were forged to build heat-health resilience. The heatwave incident in late January 2023 left five farm workers dead from heatstroke in the Northern Cape Province.[18] This incident indicates the importance of research and surveillance of heatwaves in all provinces of South Africa.

16 Kapwata T, Abdelatif N, Scovronick N, Gebreslasie MT, Acquaotta F, Wright CY. Identifying heat thresholds for South Africa towards the development of a heat-health warning system. Int J Biometeorol. 2024;68(2):381–392. URL: https://doi.org/10.1007/s00484-023-02596-z

17 Wright CY, Mathee A, Goldstone C, et al. Developing a healthy environment assessment tool (HEAT) to address heat-health vulnerability in South African towns in a warming world. Int J Environ Res Public Health. 2023;20(4):2852. URL: https://doi.org/10.3390/ijerph20042852

18 Khumalo Z. Heat wave claims lives of 5 people in Northern Cape. News24. 2023. URL: https://www.news24.com/news24/southafrica/news/heat-wave-claims-lives-of-5-people-in-northern-cape-20230120. Accessed: [8 October 2024]

Despite the rising heat due to climate change, floods are more common than drought in the Southern African Development Community region.[12] In April 2022, flooding caused significant loss of life and extensive damage to roads and infrastructure. The frequency of flooding events in eThekwini district rose from an average of ~1.1 occurrences per year between 1850 and 1899 to ~1.7 occurrences per year between 1900 and 2022.[19] The severe storms and floods in eThekwini have left many residents homeless, placing immense pressure on disaster management efforts.[25] The response and recovery efforts face significant challenges, including a shortage of personnel, insufficient funding, and a lack of capacity to implement critical initiatives. While non-profit organisations have become increasingly involved in relief efforts, the private sector's participation remains limited. Additionally, poor collaboration among internal departments within the interdepartmental committee has further hampered the effectiveness of disaster response and recovery strategies.[22] Strengthening interdepartmental coordination and fostering greater public-private partnerships are essential for improving disaster management in the region. Floods are also reported to affect tourism sites, such as national parks in South Africa, with >15 flooding hotspots in Kruger National Park and >9 hotspots in Mapungubwe National Park.[20] Although South Africa has a legal framework for disaster management, it is uncertain to what extent the government and municipalities are required by law to prevent damage caused by ever-increasing natural disasters, particularly when flooding occurs.[21]

Dust storms have been linked to poor health outcomes, including skin and eye irritation, reduced lung function, cardiovascular issues, increased hospital visits, and greater use of emergency services.[22] South Africa occasionally experiences major dust storms, particularly in the Free State and North West provinces, where their frequency increased between 2006 and 2016. Notable storms occurred in October 2014 and January 2016, with one in October 2014 originating in the Northern Cape and moving across Gauteng and North West province. In September 2019, satellite images showed that dust storms turned the skies red in Alexander Bay. While the South African Medical Research Council (SAMRC) conducted a pilot study on the health effects of these events, more research is needed to understand the full health impacts of dust storms in South Africa.

Climate change has a significant impact on maternal, foetal, and child health in South Africa.[23] Evidence of climate change-related impacts on pregnant women and children in South Africa comes from studies on hypertension during pregnancy resulting from extreme heat, malnutrition due to food insecurity, waterborne diseases, vector-borne diseases, and mental health effects.[26] The maternal medical services profiles in the Northern Cape and KwaZulu-Natal reveal a fragile health system with little resilience to climate shocks.[24] A South African follow-up case study on a representative sample of expectant mothers showed 17.9 infants per 1 000 births died within the first week of life, with the highest rates seen in North West province.[29] In North West and Northern Cape provinces, infant deaths were predicted to be more likely to occur during El Niño conditions, whereas in provinces like KwaZulu-Natal, this connection was weaker.[29] In rural Kwazulu-Natal, a significant association between miscarriages and excessive heat was seen in 3% (105/3477) of expectant mothers, with a 26% increase in the risk of miscarriage with each additional hot day.[25] As climate change progresses, the challenges associated with the reproductive health of women in hotter parts of South Africa are set to increase. However, presently there remains a paucity of studies analysing the climate change-related risks to pregnant women and children.

19 Grab SW, Nash DJ. A new flood chronology for KwaZulu-Natal (1836–2022): the April 2022 Durban floods in historical context. S Afr Geog J. 2023;1-22. URL: https://doi.org/10.1080/03736245.2023.2193758

20 Dube K, Nhamo G, Chikodzi D, Chapungu L. Mapping and evaluating the impact of flood hazards on tourism in South African national parks. J Outdoor Recreat Tour. 2023;43:100661. URL: https://doi.org/10.1016/j.jort.2023.100661

21 van der Berg A. Municipal flood management in South Africa : A critical reading of recent case law. SAJELP. 2018;(1). URL: https://hdl.handle.net/10520/EJC-1a709ae691

22 Quest. Dust storms in South Africa. Quest Online. 2022;18(1). URL: https://research.assaf.org.za/assafserver/api/core/bitstreams/641fc6e8-edb8-417e-a15c-61ae9763e3a5/content

23 Coovadia AH, Cherisch M, le Roux A, Wright CY. Climate change and the health of children in Southern Africa - The time to act is now. Wits J Clin Med. 2022;4(3):157-161. URL: https://doi.org/10.18772/26180197.2022.v4n3a5

24 Benschop ND, Chironda-Chikanya G, Naidoo S, Jafta N, Ramsay LF, Naidoo RN. El Niño, rainfall and temperature patterns influence perinatal mortality in South Africa: Health services preparedness and resilience in a changing climate. In: Akhtar R. (ed). Climate change and human health scenarios. Global perspectives on health geography. Cham: Springer; 2023. URL: https://doi.org/10.1007/978-3-031-38878-1_21

25 Moodley Y, Asare K, Tanser F, Tomita A. Maternal exposure to heat and its association with miscarriage in rural KwaZulu-Natal, South Africa: A population-based cohort study. Womens Health. 2024;20. URL: https://doi.org/10.1177/17455057241259171

Currently, there is little evidence regarding the associations between high temperatures and the risk of preterm birth, low birth weight, and stillbirths. In addition, there is insufficient epidemiological evidence of climate change-related factors that are linked to a significant rise in morbidity and mortality in pregnant women in the South African population that could be useful for informing policy – this research gap needs to be addressed. Practical adaptation plans and policies need to be revisited to meet the needs of maternal and child health in response to the impacts of climate change.[29] With the growing concerns of rising temperatures and poor air quality exacerbating challenges to foetal development, foetal and infant weight gain, maternal discomfort, and other detrimental maternal and child health outcomes, increased surveillance studies are required to characterise causative putative environmental factors.

Climate change directly affects the locations and spread of infectious diseases. South Africa is one of the leading global nations in the field of infectious disease research.[26] With one of the highest incidences of tuberculosis and HIV in the world,[27] South Africa has a large population that is vulnerable to the effects of climate change.[28] People living with HIV and AIDS are particularly vulnerable, as rising temperatures, water scarcity, air pollution, and potential water- and vector-borne disease outbreaks all have a negative impact on their already diminished immune systems.[28] Rainfall, temperature, and air quality have been linked to increased caseloads of pneumonia, asthma, malaria, and diarrhoea.[29] Similarly, a correlation between climatic variables and disease cases has been observed in hospitals in Limpopo, where the incidence of pneumonia increased after a period of lower average daily temperature and lower relative humidity.[30] These associations pose situations of concern that require careful monitoring.

The regional incidence of malaria in different parts of the world has changed over time, with climate change rendering some areas unsuitable for the life cycle of the mosquito vectors and other areas becoming more suitable for vector life cycles.[31] The incidence rate of malaria in South Africa increased to 3.95 per 1 000 population in 2017 and was linked to a lagged effect of a rise in temperatures between 2011 and 2016.[32] Historically, South Africa has experienced malaria cases in the low-lying areas of KwaZulu-Natal, Mpumalanga, and Limpopo.[33] However, with changes in meteorological conditions and the suitability of different areas for vector life cycles, monitoring and reporting of vector-borne disease cases is advised to inform changes in vector-control interventions.

Non-communicable diseases (NCDs) have not been researched as extensively as infectious diseases. Recent epidemiological evidence shows a significantly higher mortality rate due to NCDs in South Africa than previous years.[34] Several prevalent NCDs are sensitive to changes in climate. These include respiratory conditions, allergies, bronchitis, chronic obstructive pulmonary disease (COPD), type 2 diabetes, obesity, cancer of the skin and lungs, cerebrovascular disease, and cardiovascular disease.[35–36] The significant association between temperature and hospital admissions of cardiovascular disease cases in Limpopo gives some evidence that NCDs are related to climate variables.[37] Skin cancer is likely to increase with a warming climate, as incidence may be dependent on airborne pollutants, solar UVR, ambient temperature, and rainfall, among other factors related to behaviour.[38] More attention needs to be placed on epidemiological research, linking NCDs to climatic variables in South Africa.

26 Phoobane P, Masinde M, Mabhaudhi T. Predicting infectious diseases: A bibliometric review on Africa. Int J Environ Res Public Health. 2022;19(3):1893. URL: https://doi.org/10.3390/ijerph19031893
27 Kubjane M, Osman M, Boulle A, Johnson LF. The impact of HIV and tuberculosis interventions on South African adult tuberculosis trends, 1990-2019: A mathematical modeling analysis. Int J Infect Dis. 2022;122:811-819. URL: https://doi.org/10.1016/j.ijid.2022.07.047
28 Abayomi A, Cowan MN. The HIV/AIDS epidemic in South Africa: Convergence with tuberculosis, socioecological vulnerability, and climate change patterns. S Afr Med J. 2014;104(8):583. URL: https://doi.org/10.7196/SAMJ.8645
29 Kapwata T, Wright CY, du Preez DJ, et al. Exploring rural hospital admissions for diarrhoeal disease, malaria, pneumonia, and asthma in relation to temperature, rainfall and air pollution using wavelet transform analysis. Sci Total Environ. 2021;791:148307. URL: https://doi.org/10.1016/j.scitotenv.2021.148307
30 Pedder H, Kapwata T, Howard G, et al. Lagged association between climate variables and hospital admissions for pneumonia in South Africa. Int J Environ Res Public Health. 2021;18(12):6191. URL: https://doi.org/10.3390/ijerph18126191
31 Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Anna NY Acad Sci. 2019;1436(1):157-173. URL: https://doi.org/10.1111/nyas.13950
32 Leal Filho W, May J, May M, Nagy GJ. Climate change and malaria: Some recent trends of malaria incidence rates and average annual temperature in selected sub-Saharan African countries from 2000 to 2018. Malar J. 2023;22(1):248. URL: https://doi.org/10.1186/s12936-023-04682-4
33 Wright CY, Kapwata T, du Preez DJ, et al. Major climate change-induced risks to human health in South Africa. Environ Res. 2021;196: 110973. URL: https://doi.org/10.1016/j.envres.2021.110973
34 Statistics South Africa. Rising non-communicable diseases: A looming health crisis. Pretoria: Stats SA; 2024. URL: https://www.statssa.gov.za/?p=16729
35 Godsmark CN, Irlam J, van der Merwe F, New M, Rother H-A. Priority focus areas for a sub-national response to climate change and health: A South African provincial case study. Environ Int. 2019 ;122 :31-51. URL: https://doi.org/10.1016/j.envint.2018.11.035
36 Friel S, Bowen K, Campbell-Lendrum D, Frumkin H, McMichael AJ, Rasanathan K. Climate change, noncommunicable diseases, and development: The relationships and common policy opportunities. Ann Rev Pub Health. 2011;32(1):133-147. URL: https://doi.org/10.1146/annurev-publhealth-071910-140612
37 Colagiuri DR. Diabetes and climate change: Different drums – same orchestra. J Public Health Policy. 2013;34(1):165-169. URL: https://doi.org/10.1057/jphp.2012.58
38 Bühler JL, Shrikhande S, Kapwata T, et al. The association between apparent temperature and hospital admissions for cardiovascular disease in Limpopo Province, South Africa. Int J Environ Res Pub Health. 2022;20(1). URL: https://doi.org/10.3390/ijerph20010116
39 Wright CY, Norval M, Kapwata T, et al. The incidence of skin cancer in relation to climate change in South Africa. Atmosphere. 2019;10(10):634. URL: https://doi.org/10.3390/atmos10100634

South Africa's response to climate change

Legislative and policy mandates

South Africa has several legislative and policy mandates and guidelines that support its response to climate change. These include the following:

1. The Constitution of the Republic of South Africa

Section 24 stipulates that:

Everyone has the right:

a. to an environment that is not harmful to their health or well-being; and

b. to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

i. prevent pollution and ecological degradation

ii. promote conservation; and

iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

2. National Building Regulations and Building Standards Act 103 of 1977
3. National Health Act 61 of 2003
4. National Environment: Air Quality Act 39 of 2004
5. National Climate Change and Health Adaptation plan 2014/2019
6. National Climate Change Response Policy (NCCRP) 2011
7. National Environmental Health Policy 2013
8. National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health 2015
9. National Heat Health Action Guidelines: Guide to extreme heat planning in South Africa for the human health sector, October 2022
10. National Climate Change Act 22 of July 2024

South Africa's climate priorities span climate adaptation and mitigation. The South African Cabinet has approved key climate actions, including creating a Presidential Climate Commission, South Africa's Low Emissions Development Strategy, a National Climate Change Adaptation Strategy, a carbon tax, and a Just Transition Framework. Presently, South Africa is focusing efforts to fund climate change-related resilience strategies and disaster management programmes.[39] Thus, the government has worked with the private sector to establish a Climate Change Response Fund. The fund aims to build resilience by focusing on climate-proofing existing infrastructure across all types of facilities, including food systems and healthcare.

Governance and steering committees within the policy framework

The Department of Health established the National Climate Change and Health Steering Committee (NCCHSC) in 2022, which is a technical body responsible for oversight of the implementation of the National Climate Change and Health Adaptation Plan, National Heat Health Action Guidelines and other climate change activities within the Department of Health. The steering committee is comprised of stakeholders from research, academic institutions, civil society groups, national and provincial departments, municipalities, United Nations organisations, and organs of state etc. The NCCHSC recognises the need for evidence-based adaptation strategies that are cost-effective and efficient. In addition, the committee will develop nodes of expertise in health impact assessments and epidemiological studies that are urgently needed to provide much needed data that will assist in the development of adaptation strategies. In this regard, the need for more research-based evidence is highly apparent.

39 Government of the Republic of South Africa. South Africa strengthens its response to climate change. Government Communications. 2024. URL: https://www.gov.za/blog/south-africa-strengthens-its-response-climate-change

Role of the health sector

Health systems preparedness for climate resilience

Climate change-related health risks are expected to increase the burden on South Africa's already fragile health system. The most significant increases will be caused by health emergencies, increased occurrence of food and water scarcity, and vector-borne diseases, as well as the health repercussions of air pollution and poor nutrition. Moreover, health infrastructure has not been built to withstand extreme weather. Between 2001 and 2021, 56% of public health events in Africa were linked to climate change with access to service delivery and care being severely affected.[40] Among the important considerations is the selection of the location of new clinics and district hospitals by policymakers and health leaders.

Health system preparedness aims to build resilience to the impact of climate change on health and enhance the health system's ability to cope, respond, reorganise, and maintain essential functions.[41] To be resilient, health systems need to reduce their vulnerability to the impact of climate change by limiting exposure, reducing sensitivity and enhancing systems' adaptive capacity.[19] Health systems also need to increase capacity to respond to new climate change-related threats.[42] This will determine whether or not health systems recover from climate change-related impacts. The UK's Department for International Development conceptual framework for resilience adapted by the World Health Organization for health systems (Figure 3A)[43] highlights how vulnerability influences the ability of health systems to deal with disturbances like shocks and stresses from climate change. The outcomes of this resilience building range from recovery to collapse depending on health systems' ability to reduce vulnerability and improve choices and opportunities to deal with climate change-related stressors. There are many sectors involved in the operational framework (Figure 3B).

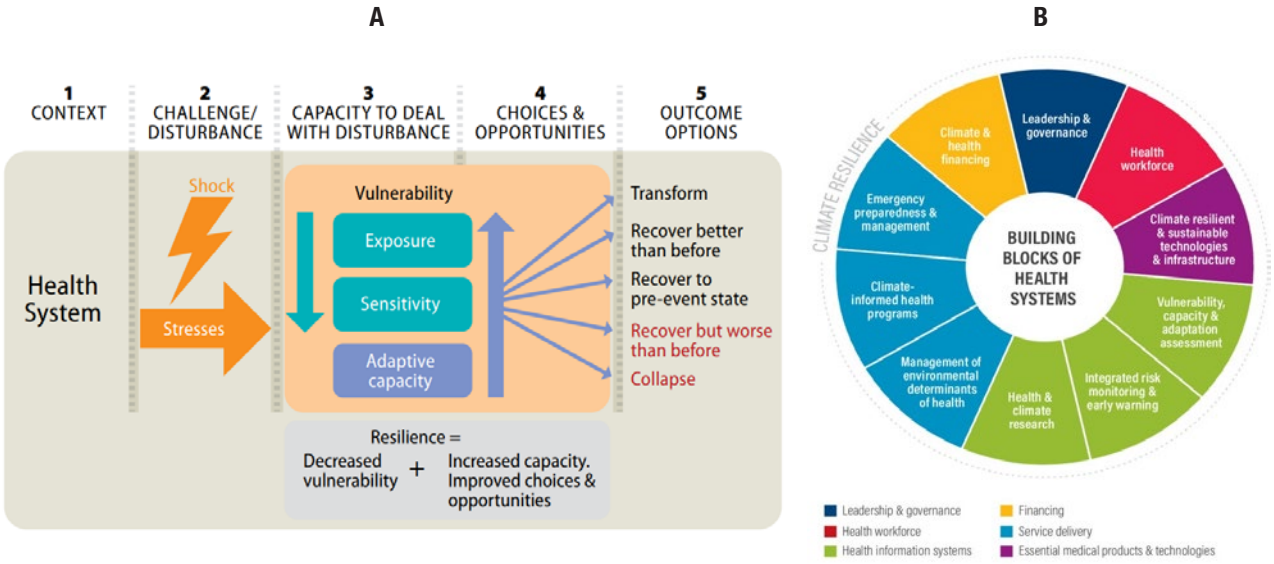

Figure 3 Operational framework for health system resilience

Source: World Health Organization, 2015.[44]

40 World Health Organization Regional Office for Africa. Africa faces rising climate-linked health emergencies. WHO. 2024. URL: https://www.afro.who.int/news/africa-faces-rising-climate-linked-health-emergencies

42 World Health Organization . Health systems resilience toolkit: A WHO global public health good to support building and strengthening of sustainable health systems resilience in countries with various contexts. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO

43 Ansah EW, Amoadu M, Obeng P, et al. Health systems response to climate change adaptation: A scoping review of global evidence. BMC Public Health. 2024;24:2015. URL: https://doi.org/10.1186/s12889-024-19459-w

44 World Health Organization. Operational framework for building climate resilient health systems. WHO. 2015. URL: https://staging.afro.who.int/sites/default/files/2017-06/9789241565073_eng.pdf

45 World Health Organization. Operational framework for building climate resilient health systems. WHO; 2015.URL: https://staging.afro.who.int/sites/default/files/2017-06/9789241565073_eng.pdf

Specifically, there are 10 components that holistically provide an integrative approach to climate resilience and allow for vertical programmes that can strengthen health systems, no matter where in the world they are based.

In summary, health systems must anticipate, respond to, cope with, and recover from climatic shocks while continuing to provide necessary services.[51] This strategy of preparedness must be integrated into all health systems and extended to non-health systems that can be determinants of illness. For a complete approach to health system readiness, the following must be examined and addressed: vulnerability and adaptation (V&A) assessments, surveillance and early warning systems, emergency preparedness and response, workforce training, public health education, policy integration and governance, climate resilient supply chains, and research and innovation.

Components of health system resilience

Vulnerability and adaptation assessments

V&A assessments aim to:

- Identify people who are most at risk to climate-related impacts, e.g., children, the elderly, pregnant women, people with pre-existing conditions, and outdoor workers.
- Evaluate health infrastructure vulnerability to identify weaknesses in the systems and analyse the ability of infrastructure to withstand extreme weather events.
- Conduct geospatial analysis to map climate risks and anticipate future health threats.
- The Department of Health, with support from the Department of Forestry, Fisheries and the Environment (DFFE) together with the German Agency for International Cooperation (GIZ), has conducted a Risk and Vulnerability Assessment in all 52 health districts.
- V&A assessments need to be conducted across all health systems, with the scope extending to sectors and communities outside of health that shape determinants of ill health. V&As should be iterative in nature and specify interventions that need to be taken in a changing climate/environment.

Health surveillance and early warning systems

There is a need for integrated risk monitoring through health surveillance and the development of early warning systems. Climate health surveillance includes monitoring for climate-sensitive infectious diseases (dengue fever, malaria, etc.) and other climate induced health risks (heat stress, respiratory and mental health disorders).

Machine learning can be used to merge health and environmental data to generate early warning systems for heat, floods, and other extreme events to support decision making and inform targeted interventions. Early warning systems should incorporate messages aimed at vulnerable populations, advising them of the necessary steps to take to protect themselves.

Emergency preparedness and response

This should entail the following:

- Disaster response planning with facilities developing plans to respond to health emergencies as a result of extreme weather events.
- Emergency stockpiling of medicines, vaccines, medical equipment, etc.
- Deployment of mobile and telehealth services to maintain essential services.

Workforce training

Some obstacles to a successful adaptation response include uncertain climate and health policy directives; a lack of understanding at the patient and community level; a lack of transdisciplinary, multi-stakeholder healthcare professional training, and an underutilised network of climate activism and justice.[45] There is a need to develop a climate and health competent workforce that has the technical and professional expertise to respond to climate impacts on health. This can be achieved through the following:

- Capacity building on the impacts of climate on health through formal and informal training.
- Preparedness and response training so that the workforce is equipped to manage climate-related health disasters.
- Identification and training of new cadres, for example, climate champions and climate health clinical specialists, to increase the health system's workforce capacity to respond.

The Department of Health has conducted training of healthcare workers in all nine provinces on the Heat Health Action Guidelines and Risk and Vulnerability Assessments. The trainings were conducted from 2022 to 2024 and over 1 000 health care workers participated.

Public health education

There is an ever-increasing need to engage communities on climate-related health risks to enable prevention and preparedness. These include:

- Education and awareness for behavioural change, for example, being well hydrated during heatwaves, minimising exposure to extreme weather elements, etc.
- Identification of adaptation and mitigation interventions at local level, for example, community shading spots, tree planting, etc.

Policy integration and governance

This can be achieved through the following:

- The development of Health National Adaptation Plans that are cascaded down to provincial and district levels.
- Multisectoral collaborations with partnerships between health, environmental, agricultural, and infrastructural sectors including Department of Social Development, etc. to adequately respond to the complexities of climate change.
- Climate health financing to fund health adaptation and mitigation interventions at scale.

Climate resilient supply chains

Supply chains need to be strengthened to ensure that:

- Essential medicines and medical equipment are available during times of climate-related disasters.
- Climate sensitive medical products, such as temperature sensitive medicines and vaccines are transported and stored in a manner that they remain efficacious.

Research and innovation

There needs to be investment in the following:

- Climate and health research funding to generate local knowledge on the effect of climate change on communicable and non-communicable diseases, maternal and child health, nutrition, mental health, etc.
- Technologies, for example, digital health technologies that can be deployed during climate disasters.
- Innovations to develop climate-sensitive medical products.

45 Maimela, G. Strengthening health systems for mitigating climate change: responding to climate change as public health professionals. Wits J Clin Med. 2022;4(3):181. URL: https://doi.org/10.18772/26180197.2022.v4n3a9

Health surveillance

Health surveillance for well-established (or reasonably well-established) health outcomes associated with heat exposure needs to be developed. The effects of extreme weather are easily recognised, but the gradual increase in temperature across the country contributes to hidden epidemics that need attribution and detection studies.[46] Data need to be available to monitor various health outcomes in the context of climate change. For instance, among the numerous conditions that are directly associated with heat, it may not be immediately apparent that chronic kidney disease is attributed to chronic heat exposure. More complex conditions (for example, reproductive outcomes) may not be easily associated with heat exposure. However, these outcomes need to be continuously monitored to consider future impacts from a changing climate to ensure prevention of adverse health effects.

Environmental surveillance

The IPCC Sixth Assessment Report indicates evidence of rising heat extremes and an increase in the frequency and intensity of heavy precipitation events, that are currently significant climate change-related risks across Africa and are set to persist during the 21st century.[47] Therefore, monitoring environmental variables associated with these climate change drivers is critical to inform intervention and mitigation policies aimed at reducing the impacts of climate change on health. Previous studies have summarised key environmental indicators proposed by several stakeholders for surveillance of climate change-related public health outcomes.[48] Table 1 presents the variables that are useful to monitor temperature and precipitation in South Africa. It is important to note that there is a lack of research on cold extremes, not only in South Africa but also in Africa. However, research has shown that low temperatures have more significant adverse impacts on health outcomes compared to high temperatures.[49] This indicates the importance of metrics to monitor cold extremes that should be included as environmental indicators in the Global South.

Table 1 Environmental indicators of climate change with South African studies that have used these indicators

Variable	Metric	Studies from South Africa
Temperature	Maximum, minimum, mean and diurnal temperature	Scovronick N, Sera F, Acquaotta F, et al. **The association between ambient temperature and mortality in South Africa: A time-series analysis.** Environ Res. 2018;161:229-235. URL: https://doi.org/https://doi.org/10.1016/j.envres.2017.11.001 Kapwata T, Abdelatif N, Scovronick N, Gebreslasie MT, Acquaotta F, Wright, CY. **Identifying heat thresholds for South Africa towards the development of a heat-health warning system.** Int J Biometeorol. 2024;68(2):381-392.
	Future projections of extreme heat	Mbokodo I, Bopape M-J, Chikoore H, Engelbrecht F, Nethengwe N. **Heatwaves in the future warmer climate of South Africa.** Atmosphere. 2020;11(7):712. Engelbrecht F, Adegoke J, Bopape M-J, et al. **Projections of rapidly rising surface temperatures over Africa under low mitigation.** Environ Res Lett. 2015;10(8):085004.
	Extreme heat days and heat events	Meque A, Pinto I, Maúre G, Beleza A. **Understanding the variability of heatwave characteristics in southern Africa.** Weather Clim Extrem. 2022;38:100498. URL: https://doi.org/https://doi.org/10.1016/j.wace.2022.100498 Kapwata T, Gebreslasie MT, Wright CY. **An analysis of past and future heatwaves based on a heat-associated mortality threshold: Towards a heat health warning system.** Environ Health. 2022;21(1):112. URL: https://doi.org/10.1186/s12940-022-00921-4
	Aridity (drought/dryness)	Benschop ND, Chironda-Chikanya G, Naidoo S, Jafta N, Ramsay LF, Naidoo RN. **El Niño, rainfall and temperature patterns influence perinatal mortality in South Africa: Health services preparedness and resilience in a changing climate.** In: Akhtar R. (ed) Climate change and human health scenarios. Global perspectives on health geography. Cham: Springer; 2023. URL: https://doi.org/10.1007/978-3-031-38878-1_21

46 Ebi KL, Åström C, Boyer CJ, et al. Using detection and attribution to quantify how climate change is affecting health. Health Aff. 2020;39(12):2168-2174. URL: https://doi.org/10.1377/hlthaff.2020.01004

48 Intergovernmental Panel on Climate Change. Africa. In: Pörtner DC, Roberts M, Tignor ES, et al. (eds). Climate change 2022: Impacts, adaptation and vulnerability. Cambridge: Cambridge University Press, 2023; p.1285-45. URL: https://doi.org/10.1017/9781009325844.011

49 Moulton AD, Schramm PJ. Climate change and public health surveillance: Toward a comprehensive strategy. J Public Health Manag Pract. 2017;23(6):618-26. URL: https://doi.org/10.1097/PHH.0000000000000550

50 Seltenrich N. Between extremes: Health effects of heat and cold. Environ Health Perspect. 2015;123(11). URL: https://doi.org/10.1289/ehp.123-A275

Rainfall	Heavy precipitation days, heavy precipitation events, total rainfall from heavy precipitation events	Manhique A, Reason C, Silinto B, et al. **Extreme rainfall and floods in southern Africa in January 2013 and associated circulation patterns.** Nat Hazards. 2015;77:679-691. Sen Roy S, Rouault M. **Spatial patterns of seasonal scale trends in extreme hourly precipitation in South Africa.** Appl Geog. 2013;39:151-157. URL: https://doi.org/https://doi.org/10.1016/j.apgeog.2012.11.022

The need for climate change and health indicators

Climate change-related health indicators are crucial for a country as they enable policymakers to monitor the direct and indirect health impacts of climate change on its population. As global temperatures rise, countries face increased risks of heatwaves, natural disasters, and the spread of vector-borne diseases like malaria and dengue. Health indicators allow governments to track how these factors are affecting public health, providing the data needed to allocate resources, design public health interventions, and create policies that protect vulnerable populations. Without such indicators, it becomes difficult to measure the effectiveness of mitigation and adaptation strategies, leaving the population more vulnerable to climate-related health crises.

Additionally, climate change-related health indicators help raise public awareness and foster international cooperation on climate issues. By gathering comprehensive data on health impacts, countries can contribute to global efforts to combat climate change, share best practices, and learn from the experiences of others. These indicators also provide a framework for holding governments accountable, ensuring they prioritise public health in their climate policies. In doing so, countries can better protect their citizens' health while contributing to the global fight against climate change.

South Africa is in the process of developing climate change-related health indicators, building on existing datasets but also calling for new surveillance systems to ensure that all climate change-related health outcomes are carefully monitored.

Drawing on the international literature, below is a comprehensive list of potential climate change and health indicators, which could be considered for implementation in South Africa.

Table 2 Climate change related indicators and associated impacts on health

Indicator	Health impact/s	Health outcomes
Extreme heat events	Heat related illness/ mortality	Incidence of heat stroke, heat exhaustion and other heat-related health conditions Increased rates of hypertension, heart attack episodes and strokes (myocardial infarction) Hydration-related disorders Occupational heat stress: incidence of heat-related illnesses and injuries among outdoor and manual labour workers due to rising temperatures (e.g., chronic kidney disease)
	Food-borne illnesses	Increased rates of illnesses from bacteria like Salmonella or *E. coli* that thrive in warmer temperatures
Air pollution (includes emissions and wildfires)	Respiratory diseases	Increased rates of asthma, acute presentation of wheeze episodes particularly among children, chronic obstructive pulmonary disease, and other respiratory conditions linked to poor air quality More emergency room visits for asthma–correlation with higher levels of air pollutants and allergens during climate events
	Cardiovascular diseases	Increased rates of heart attacks and strokes
	Skin cancers	Linked to increased exposure to UV radiation due to ozone layer depletion–influence of emissions
Extreme weather events	Mental health impacts	Increased incidence of stress, anxiety, and depression related to climate disasters, displacement, or environmental changes
	Displacement-related health impacts	Health conditions linked to migration and displacement caused by climate-related disasters
	Mortality	Deaths and injuries from floods, hurricanes, droughts, wildfires, and other natural disasters
	Health system	Disruptions in medical services and destruction of key infrastructure - such as electricity and water provision Increased hospital admissions Detrimental impact on the capacity and resilience of healthcare infrastructure
	Food security	Increased rates of malnutrition or undernutrition linked to disruptions in food supply
Floods and droughts	Waterborne diseases	Incidence of cholera, diarrhoea, and other illnesses from contaminated water, often worsened by floods or drought
	Water access and/or quality	Reduction in availability of safe drinking water in areas affected by drought or contamination from climate events

Climate change (combination of change in temperature, rainfall)	Disease patterns, prevalence, and transmission rates	Prevalence of diseases like malaria, dengue, Zika virus, and Lyme disease are influenced by changing temperature and precipitation patterns Changes in incidence of infectious diseases due to shifting ecosystems and increased human-wildlife interaction Changes in the geographical range of disease vectors, such as mosquitoes and ticks
	Infant and child health outcomes	Increased incidence of vitamin and mineral deficiencies resulting from decreased food diversity and quality Impact on children's health, such as birth weight or developmental delays linked to maternal nutrition during extreme weather events
	Nutrition	
	Allergies	Rates of pollen-related allergic reactions increase with longer pollen seasons due to warming temperatures

Conclusion

Preparedness in the health sector is essential to mitigate the growing threats posed by climate change. Rising temperatures, extreme weather events, and shifts in disease patterns are already straining healthcare systems worldwide, making it critical for nations, including South Africa, to strengthen their public health infrastructure. By integrating climate change into health preparedness plans, countries can better anticipate and respond to the wide range of health challenges exacerbated by a changing climate, such as heat-related illnesses, food and water security issues, and emerging infectious diseases. A proactive approach, with an emphasis on prevention and resilience, is key to protecting the well-being of communities in the face of an increasingly unstable environment.

A crucial part of this preparedness involves embedding climate change-related health indicators into routine health surveillance. These indicators will provide the necessary data to track health trends associated with climate change, enabling timely interventions and informed policymaking. Without this integration, South Africa risks being unprepared for future health crises linked to climate change. Now is the time for decisive action, government, health organisations, and communities must collaborate to incorporate these indicators into the national health system, to ensure that the country's health sector is equipped to face the challenges of a warming planet.