Towards a Health Vulnerability Index for Extreme Weather Events

Report
to the Water Research Commission

by

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October 2025

WATER
RESEARCH
COMMISSION

This is the final report of WRC project No. C2021-2022-00407.

EXECUTIVE SUMMARY

BACKGROUND

Extreme weather events (EWEs) are predicted to increase globally, necessitating an in-depth understanding of the extent to which these events may detrimentally affect human health. To manage risks to health appropriately, an understanding of the health-related risks associated with extreme weather events needs to be developed with the specific context in mind. This project provides three phases (desk-based review, group workshopping frameworks, and community engagement) to begin to unpack these risks and to develop some indicators to assess health vulnerability in the context of EWEs.

AIMS

The following are the aims of the project:

1. To define the drivers and patterns of vulnerability and risk during extreme weather events
2. To develop an understanding of how these vulnerabilities and risks might change over time
3. To determine how these risks specifically affect human health, including short-term and long-term considerations (communicable and non-communicable diseases, as well as healthcare human capacity, and related healthcare provision resource demands)
4. To understand the short-term and long-term impact of extreme events on health vulnerability
5. Provide a framework that can assist at the local level for the development of context-specific HVIs.

METHODOLOGY

The project made use of a systematic scoping review to develop an understanding of the evidence base associated with extreme weather events and human health outcomes. From there, the project drew on a health pathways approach to work backwards from these health outcomes to develop a framework to explore vulnerability to these specific outcomes. Thereafter, the project team took this draft framework to a number of neighbourhoods to engage with residents who had experienced EWEs to further workshop the frameworks and associated self-assessment materials to refine these materials.

RESULTS AND DISCUSSION

We offer an intricate mapping of health outcomes and potential indicators. We suggest that these indicators are useful building blocks to begin engagement around health outcomes and EWEs to develop context-specific health vulnerability indicators (HVIs) for areas or regions in southern Africa. These indicators offer a starting point, but further research is needed as these tools (including the pathways/indicators for health outcomes) can be used in a variety of ways, dependent on end users and aims.

GENERAL

A draft framework for an HVI associated with specific EWEs has been developed, user-tested and feedback sessions to incorporate missing details/improve the usability of the tool have been completed. Further research to calibrate the tool and further validate the indicators is needed.

CONCLUSIONS

While it is evident that there are a number of clear indicators for health vulnerability in relation to extreme weather events that are consistent across the vast diversity of spaces in Cape Town or southern Africa, the frameworks proposed in this research require more rigorous engagement and discussions across different settings and types of resident experiences.

RECOMMENDATIONS

- Evidence-based indicators are only as good as the research that has been done – there are many gaps in the evidence base, and thus, we suggest more research specific to the southern African context around people's health outcomes when faced with EWEs is an area of need.
- The indicators (questions related to health pathways towards outcomes) we have provided are useful as building blocks to understand pathways to specific health outcomes, but we recommend that these only be used in consultation with local residents to understand their local validity and usefulness.
- The scoring system we offer should be further refined with more dedicated research to understand where score ranges should be cut off in relation to categorizations of types of vulnerability.
- Making use of these indicators requires that users understand that these self-reported indicators are relative, and subjective – they are, as their name suggests, indicators, and not necessarily clear pictures of lived realities.
- This research has highlighted the difficulty in decoupling socio-economics and health vulnerabilities, particularly those associated with household locations and neighbourhoods; as such, major planning shifts are needed, as are simple interventions like attending to changing housing materials where possible; in the context of extreme temperatures, for example, alternatives to zinc roofing should be sought.
- These indicators and frameworks should be used in concert with already existent (and validated) CRVAs, including those specific to southern Africa, like the Greenbook; efforts undertaken using top-down approaches by national and local departments of health; and weather science projections and early warning systems.
- Early warning systems for storms are important processes to make residents most affected by EWEs aware; these systems should be widely accessible to public so that acute health experiences related to EWEs can be avoided.
  Planners, policy-makers and other municipal officials should heed the data outcomes and experiences relayed in this report, and consider the value of water-sensitive design and urban resilience planning, including attention to drainage and infrastructure accessibility, alongside these specific health outcomes to address hazards associated with EWEs.

ACKNOWLEDGEMENTS

The project team wishes to thank the following people for their contributions to the project:

Reference Group	Affiliation
Dr Eunice Ubomba-Jaswa	Water Research Commission (Chairperson)
Ms Penny Jaca	Water Research Commission (Project Administrator)
Dr Thandi Kapwata	Medical Research Council
Dr Tessa Moll	University of the Witwatersrand
Ms Katlego Ncongwane	South African Weather Service
Dr Joel Botai	South African Weather Service

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ACRONYMS & ABBREVIATIONS

HVI	Health vulnerability index
EWE	Extreme weather event

CHAPTER 1: BACKGROUND

1.1   INTRODUCTION

The frequency of extreme weather events (EWEs) is predicted to increase globally, necessitating an in-depth understanding of the extent to which these events may detrimentally affect human health. The fundamental requirements to ensure health, including access to potable water, sewerage disposal, clean air to breathe, sufficient food, and shelter, can all be affected by changes in climate [1-4]. Less or more rainfall will affect access to clean water, food supplies and drainage systems that are intended to move sewerage away from residential areas and farmland. Changes in average temperatures or seasonal patterns affect food supplies, and air and water quality [5-7]. As all parts of an ecosystem are integral to the overall functioning of the system, the health of humans, as part of that system, is interrelated to these changes in the environment. The challenge is to fuse sustainability science with social and biomedical approaches centred on human health and well-being [8]. The World Health Organization (WHO) acknowledges that the risk factors associated with climate change have the potential to affect human health [9], but little research has been done in sub-Saharan Africa to understand links between health trends, associated risks and climate patterns [5, 10, 11]. To manage these risks to health appropriately, an understanding of the health-related risks associated with extreme weather events needs to be developed with the specific context in mind. All too often, risk assessments of climate events are based on the hazards that populations are exposed to during events and the corresponding coping mechanisms – these are too narrowly focused. The health vulnerability of populations must also take into account precariousness, or cases where populations move from one extreme weather event (drought) to another (flooding), or where these events are concomitant. South Africa, with its diverse climatic zones and the wide range of existing challenges, provides the perfect case study for understanding these precarious health vulnerabilities in the face of rapid climate change.

In line with contemporary understanding of Health and Climate Vulnerability indices, this project aims to develop a framework that offers a method by which localities and regions can develop their own health vulnerability indices that are locally relevant, context-specific and aimed at being usable by local persons. What will be offered in "An evidence-based review of the health effects of extreme weather events: towards developing a health vulnerability index (HVI)" is an extensive literature review to support the development of a framework, and then user testing of the framework in a number of localities (if COVID restrictions are lifted). With that said, it is important to note that this project is not able to provide an HVI that is generalisable as such, but rather a framework that can assist at the local level for the development of context-specific HVIs.

Cochrane systematic reviews provide the most comprehensive and in-depth framework for peer-reviewed systematic reviews [12]. This form of evidence-based analysis has multiple levels of peer-review and provides one of the most thorough formulas for ensuring a wide range of evidence-based research is included in the analysis, involving critical engagement with the forms of data available. Following the general framework of a Cochrane review, we propose to engage in a thorough and peer-reviewed process of developing search strategies and working with university search technicians to develop an evidence-based review of health effects of extreme weather events with the aim of using these materials to collaboratively (with various stakeholders, including the general public) develop a health vulnerability index for various South African contexts. However, due to the time-intensive process of Cochrane reviews, and the expansive nature of the literatures available on this topic we have engaged in a scoping review that draws on Cochrane resources and skills but without undertaking a formal Cochrane registration process as this would make the project's intended timeline far exceed that set out by the Water Research Commission (WRC) for this project. Instead, this project draws on the Cochrane process, where multiple authors review each study for inclusion and data extraction, to provide a scoping review drawing on a rapid evidence review process [13] at the end. This scoping review thus maintains a structured and rigorous search and data extraction process, but does not limit evidence extraction to a specific type of study. In addition, the scoping review aims to cast a wide net to understand what data is available on the topic of extreme weather events in relation to human health. As such, this scoping review will provide insights into what evidence is available, what

research is being done, and where there are gaps in the evidence base. This scoping review will provide specific endpoints and outcomes related to human health in extreme weather events in order to inform the development of a community-usable health vulnerability index for extreme weather events.

1.2   PROJECT AIMS

The following are the aims of the project:

1. To define the drivers and patterns of vulnerability and risk during extreme weather events;
2. To develop an understanding of how these vulnerabilities and risks might change over time;
3. To determine how these risks specifically affect human health, including short-term and long-term considerations (communicable and non-communicable diseases, as well as healthcare human capacity, and related healthcare provision resource demands);
4. To understand the short-term and long-term impact of extreme events on health vulnerability;
5. Provide a framework that can assist at the local level for the development of context-specific HVIs.

1.3   SCOPE AND LIMITATIONS

It is important to note at the outset, between our initial proposal and the development of the protocol for the systematic review for this project, we determined that it is more appropriate to undertake a rapid scoping review, as reported in the inaugural reference group meeting, due both to time constraints and the volume of studies generated from our search. This did not change the deliverables or our systematic review process, but does mean that the scope of our analysis has expanded. The large volume of studies identified through our search also required more time than originally scoped. In addition, as described in detail in team members' contributions, our efforts to recruit student researchers were met with many challenges – some team members were unable to meet the MOUs set out for their role, while other team members moved overseas for other jobs/study opportunities. This meant that the data analysis phase of this research, although planned to take 6 months, took 9 months in total.

COVID restrictions made large parts of the originally proposed project (i.e., the participatory workshops to ground-test the HVI in local contexts) very difficult to complete. In consultation with WRC, the original timeline for this project was changed to accommodate the possibility for engagement with residents who had experienced the EWEs in question – extending the project into 2022. While we had originally planned for 6 months of engaged field work with a minimum of two focus groups, we were only able to conduct 2 months of field work and workshopping over February and March 2022 with four focus groups and a number of individual interviews. With this in mind, the engaged aspects of this research are limited, and more field research is needed to ground-test the usefulness of the proposed HVI frameworks. This is not unexpected, as the framework was always proposed to be a draft, and more testing in engagement settings would always have been needed.

Team members' contributions:
Amber Abrams has led the project as PI. Taherah Asmall earned her MPH while completing the analysis of drought events (2019 – 2020) and has joined the team as a research assistant. Michaela Deglon is an MPH student working on the project and using some of the methods learned in this project for her MPH thesis. Demilade Fayewimo was hired as a postdoctoral fellow and joined the team to learn about the systematic review and scoping process. She joined the team for six months, but took up a position overseas before completing her fellowship (in October 2021). Louise Wang and Siri Kanakala were interns with Future Water, based in the United States, as undergraduate students; they contributed significant time to the screening process and to learning the systematic/scoping methods. Lethabo Makgoba, an MPH student, joined the team in November 2021 and provided significant input in the final screening and data extraction processes, as well as the team workshops to build the framework. Ridah Perrin was hired as an honours student in November 2021 to assist with data extraction; he has continued engaging with the project through the intensive workshopping period (late January – February) to develop the draft framework for

engagement events – he has since enrolled in an MA with the hopes of expanding on the HVI research from an anthropological perspective. In November 2021, we recruited two PhD candidates to assist with data extraction and focus group set-ups; both PhD students had extensive experience in engagement research. Unfortunately, both students suffered family tragedies and health challenges in the interim and were not able to meet the MOUs set out during their hiring. Sithabihle Hlahla, a postdoctoral fellow, joined Future Water on 1 February 2022 and was extensively involved in the development of the framework with MPH students (Lethabo and Michaela), Taherah Asmall and Ridah Perrin. In addition, during this period, a recent medical student graduate (Nomzamo Tshuma), interested in the work of Future Water, joined the team to support our workshops and discussions. Dr Kirsty Carden and Prof Aqiel Dalvie are mentors on this project. They have engaged with the draft documents and offer project support when needed. In this way, this project has been very successful in training, mentoring and developing young researchers in the method of systematic reviewing, and at the same time, introducing a young cohort to thinking around human health in the context of climatic changes and EWEs. In fact, Perrin has requested to engage with the work done and continue efforts for his Master's in Social Anthropology; he will submit a research proposal for consideration through his department.

CHAPTER 2: EXTREME WEATHER EVENTS (EWES) AND HUMAN HEALTH OUTCOMES SCOPING REVIEW

2.1 INTRODUCTION AND BACKGROUND

The effects of climate change and global warming have become increasingly apparent and research on how these changes impact human health has increased tremendously [14]. Climate change is defined by climate variability and extreme weather events, including changes in the ambient and peak temperatures, humidity, water salinity, precipitation, an increase in heat waves, and rising sea levels [15]. In the last 50 years, global warming has been largely attributed to the increase in greenhouse gas (GHG) emissions, which has altered physical and biological systems [16]. For example, the global surface temperature is expected to increase, relative to the 1850-1900 period, by 1.5 °C by the end of the 21st century [17].

The association between climate variability and infectious disease transmission, such as cholera, diarrhoeal diseases, West Nile virus and malaria, is well documented [18]. Additionally, climate change will impact on nutritional health in cases of reduced food availability or reduced nutrient concentration of available foods and increased food prices [14]. Climate change has been associated with mental health concerns, ranging from minimal distress symptoms to clinical disorders such as post-traumatic stress disorder [19]. Extreme weather events will impact health globally, with the poor and vulnerable populations being disproportionately affected [14]. This rapid scoping review explored extreme weather events, separated into the following categories (1) Extreme heat and heat waves; (2) Wildfires and smoke inhalation (3) Flooding and storms and (4) Drought.

2.2 OBJECTIVES

The study aimed to review the available research on the health impacts of extreme weather events in Africa, with the intent of developing a framework for a Health Vulnerability Index (HVI) for South Africa.

The study objectives were as follows:
- To perform a rapid scoping review for the identification and extraction of literature on the direct and indirect adverse health effects associated with extreme weather events, i.e. heat waves, wildfires, flooding and storms.
- To comprehensively identify the type(s) of health-related extreme weather events and provide insight into the available evidence on these effects.
- To identify vulnerable populations and use data from the present study to direct future developments of a health vulnerability index for South Africa.

2.3 METHODS:

Due to the limited timelines available in this project, a scoping review, using a rapid evidence review (RER) process, was undertaken, as such a review allowed for a "structured and rigorous search" that includes "quality assessment of the uncovered evidence," however, a RER is "not as extensive and exhaustive as a systematic review" [13]. A RER assists in quickly identifying available evidence and gaps in the literature. According to Godsmark and Irlam (2019) and Godsmark et al (2019) [20, 21]. The main extreme weather events occurring in South Africa included extreme heat/heat stress, drought, wildfires (and associated smoke inhalation), flooding and storms. We understand these events are often interrelated as outlined in Figure 1.
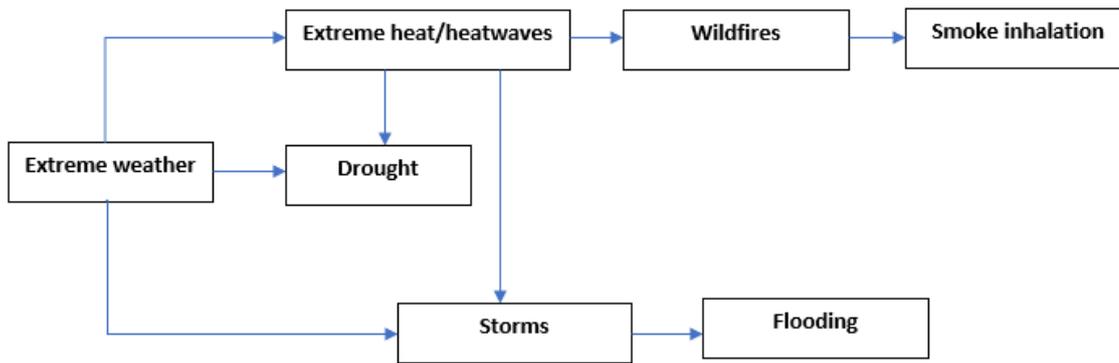
Figure 1: Extreme weather events occurring in South Africa

2.3.1   Search strategies development

An extensive electronic literature search for published and unpublished studies was conducted. Articles were searched using a combination of keywords, Medical Subject Heading (MeSH) terms and free text words (see Appendix A for search strategies).

The development of a feasible search strategy required directed questions to retrieve articles that were relevant to the study objectives. Three variables that we needed to define were the exposures, outcomes and location. The exposures, extreme weather, were identified as extreme heat/heat stress, drought, wildfires (and associated smoke inhalation), flooding and storms. Given the limited timeframe available, the exposures were grouped together (Fig 2) as follows:
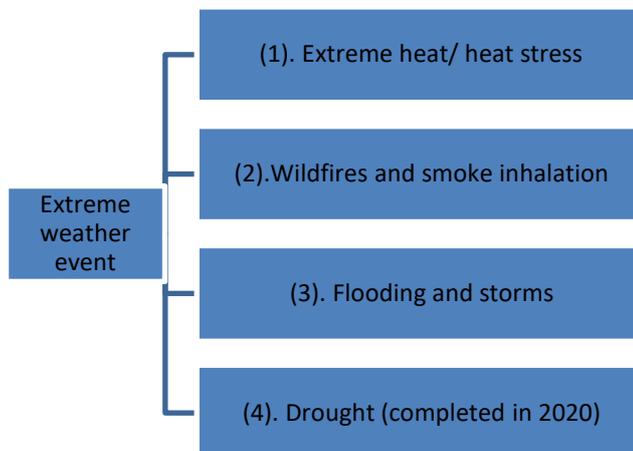
Figure 2: Categorisation of extreme weather events common in South Africa

The health effects associated with categories (1), (2) and (3) were explored in depth between April – December 2021. Research on the adverse health effects associated with drought, category (4), was completed in 2020 [22]. In order to obtain all the relevant information on the health-related extreme weather events, it was decided to develop three separate search strategies. To avoid duplication of results, each strategy had a different time frame based on the most recently published reviews for each EWE category. This meant that for flooding and storms, articles published from 2016 to 2021 were included. For heatwaves and wildfires, those published from 2007 to 2021 and 2015 to 2021, respectively, were included (See inclusion criteria below). The outcome, i.e., health effects, was kept non-specific so as not to limit the results obtained. While the objective of this project has been to create

an HVI for South Africa, articles published throughout Africa were included to understand the wider context, and where data on specific topics may be limited in South Africa.

2.3.1.1 Defining exposure variables

To comprehensively define the three study variables, a mini-literature search was conducted, in which approximately 200 published and unpublished articles were collectively reviewed. These articles included existing systematic review papers and original studies. Thereafter, a list of each exposure variable was collated. The list below, while exhaustive, may not have included other methods used to define the exposure variables. Owing to this, in cases of ambiguity, the authors discussed the eligibility of individual studies.

Existing reviews on heatwaves/extreme heat, wildfires, flooding and storms do not adhere to strict definitions of these variables and tend to use different methods to classify exposure. However, where possible, these variables were broadly classified as follows:

Heat waves:
- Summer temperatures that were higher/hotter than the normal average per given location
- The Bureau of Meteorology criterion:
    - ≥5 consecutive days with Tmax ≥ 35 °C or
    - ≥3 consecutive days with Tmax ≥ 40 °C
    - >3 consecutive days of dry-moderate or moist-tropical plus type weather
- Approximately 3 days when maximum temperatures were > 30.0°C
- Assessment of individual studies based on maximum temperature (Tmax), mean temperature (Tmean), thermal indices that consider additional atmospheric variables such as humidity, wind speed, and solar exposure

Wildfires:
- An uncontrolled fire that burned in the wildlands, forests, grasslands, savannas, and other ecosystems
- Fires referred to as bushfires, forest fires, woodland fires, grassfires, and peat fires that are caused by climatic factors such as lightning
- Identification of fire-affected areas using Moderate Resolution Imaging Spectroradiometers (MODIS) or other imaging techniques
- Studies that measured PM2.5 due to smoke events AND were able to ascribe this to wildfires specifically.

Flooding and storms:
- A flood was defined as an overflow of a natural stream/water body, which includes fluvial, pluvial, flash, urban and coastal floods due to climatic factors such as continuous rainfall
- Flooding is defined as an unusual inundation of areas with water, due to climate-related factors such as storms
- A storm is defined as an atmospheric disturbance resulting in rain showers, snowstorms, thunderstorms, gales, tornadoes and tropical cyclones
- A storm occurring due to low-pressure, strong wind cyclones (ranging from 103-117 km/hr) with heavy precipitation
- Rotating storm system occurring over water, with a wind speed of >34 knots
- Classification of an area as a "disaster area" based on the Centre for Research on the Epidemiology of Disasters' (Brussels, Belgium) International Disaster Database guidelines criteria:
    - 10 or more people were reportedly killed.
    - 100 or more people reported affected.
    - A declaration of a state of emergency or call for international assistance.

Drought:
As mentioned previously, the study on the adverse health effects associated with drought in Africa was completed in 2020 and published in 2021. In this study, drought was defined by common definitions used by ecologists and summarised in Slette et al [23]. Drought was defined as:
- Dry conditions, which represented reduced water availability and absent or deficient rainfall
- Precipitation events that differed from the normal (below 25%) for a given site

_____

- Negative Standardized Precipitation Evapotranspiration Index (SPEI)
- Low water flow and low soil moisture for a given site.

2.3.2 Data Collection and Analysis

2.3.2.1 Study selection

In this review, articles were identified, screened, assessed for eligibility and included according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines [24]. The titles and abstracts of articles were first screened by authors who assessed whether they met the inclusion criteria. More than 350 screened full texts were read to consider eligibility. Articles not meeting the inclusion criteria were removed.

2.3.2.2 Data extraction and management

Extracted data was added to summary tables (see section 2.4), which included author name(s) and year of publication, article title, methods, climatic exposure(s), health outcome(s) investigated, additional study findings and relevance of the study to HVI. Due to the parameters of the inclusion criteria, quantitative meta-analysis was not conducted due to the heterogeneity of the studies identified. However, quantitative results from individual studies were summarised.

2.3.2.3 Assessment of risks and bias

Experimental studies on extreme weather events were not plausible; therefore, the studies included were predominantly observational and qualitative in nature. Assessment of risk and bias of individual observational studies was done using the Critical Appraisal Toolkit (CAT). Studies with obvious weaknesses were excluded following consultation with other authors. When doing quality assessment and both reviewers disagreed, but provided sufficient motivation for their various assessments, we deferred on the side of caution and 'downgraded'. For example, if one author assessed an aspect as 'strong' and another 'moderate', both with good support, we chose the moderate motivation, unless both authors felt the higher grading was more appropriate.

2.3.3 Inclusion/Exclusion criteria

2.3.3.1 Inclusion criteria

A study was eligible if it complied with the inclusion criteria listed below:
- Based on the most recent published review on the effects of heat waves on health (Luber and McGeehin, 2008) [25] articles published from 2007 onwards for this category were included
- Based on the most recent published review on the effects of flooding and storms on health (Saulnier et.al, 2017) [26] articles published from 2016 onwards for this category were included
- Based on the most recent published review on the effects of wildfires on health (Reid et.al, 2016) [27] articles published from 2015 onwards for this category were included
- Fires which were described as "natural" fires and result from climate change, only e.g., wildfires caused by extreme heat or drought, were included.
- Flooding caused by climatic factors only, such as cyclones, typhoons, heavy rains and tropical storms was included
- Studies published in English
- Studies that have an objective measure for heat wave, flooding and storm classification
- Studies that deal with a clear association between one or more of the study's climatic extremes and adverse health effects in humans
- Studies with comparative and non-comparative study designs
- Observational studies
- Studies performed in any region and any subgroup in Africa

- Participants of all ages and sex

2.3.3.2 Exclusion criteria

A study was not eligible if it met any of the exclusion criteria listed below:
- Studies published in a language other than English
- Studies that addressed the effects of climatic extremes on other species, such as microorganism growth, without being linked to an adverse human health effect
- Studies with a systematic or review study design
- Controlled prescribed fires or fires caused by human negligence were excluded.
- Studies on occupational exposures were excluded as the overall fire exposure cannot be attributed solely to climate-induced wildfire exposures (i.e., EWEs).
- Studies on the exposure to indoor or outdoor fuel burning for household purposes were excluded.
- Studies without an objective measure of the exposure variables were excluded

2.4 RESULTS

Data and evidence related to wildfire were extremely limited, whereas with extreme heat, drought, and flooding, there was ample relevant research available for analysis. The PRISMA diagrams (Figures 3 – 5) below outline the search results and screening process, providing a breakdown of how many studies were screened and how many were included for extraction once screening was completed.

Figure 3: PRISMA Flow for Drought

(see [22] Asmall et al 2021)
1943 references imported for screening AND 53 additional records sourced
74 duplicates removed
1922 studies screened against title and abstract
1890 studies excluded
32 studies assessed for full-text eligibility
17 studies excluded with reasons
15 studies included

Figure 4: PRISMA Flow for Heat, Flood and Storm combined search

11421 references imported for screening as 11420 studies
1258 duplicates removed
10162 studies screened against title and abstract
9796 studies excluded
366 studies assessed for full-text eligibility
291 studies excluded
75 studies included

Figure 5: PRISMA Flow for Wildfire search

185 studies imported for screening
10 duplicates removed
175 studies screened
154 studies irrelevant
21 full-text studies assessed for eligibility
21 studies excluded
0 studies included

Wildfires and smoke inhalation

The available research focused on wildfires and their influences on human health in a southern African context was extremely limited. In fact, as Figure 5 (above) shows, zero studies were included in our review (out of a possible 185 screened). This is likely due to the reality that determining the difference between wildfire and fires directly generated through anthropogenic activities was difficult and problematic when part of a strict exclusion criterion. We note that wildfire smoke is likely very different from urban fire smoke, and for this reason, we excluded all studies where fire and human health were explored, but fire was not consistent with veld burning. In this way, we acknowledge that the lack of data is partially driven by our exclusion criteria, but with no evidence from which to develop a framework, this component of our research is underdeveloped and incomplete.

Extreme temperatures: cold, heat and heat waves

Anthropogenic activities have led to a rise in temperatures over the last century resulting in an increase in the frequency and intensity of heat waves (Campbell et.al, 2018). Data was extracted from 18 studies exploring the impacts of extreme temperature, as shown in Table 2.1. Extreme heat and heatwaves were found to be associated with an increase in the odds of having a miscarriage/stillbirth, undernourishment, wasting and underweight in children, a decrease in stunting in children under 2 years, an increase in conflict, homicide and suicide, increase in mortality, premature death from non-communicable diseases (only women had a statistically significant increase in mean daily NCD-YLL with extreme cold), increased risk of spontaneous pneumothorax, hospital admissions related to climate-sensitive diseases and hospital admissions for cardiovascular diseases (CVD). Symptoms of heat-stress that were found included fatigue, thirst, sweating, weakness, dizziness, muscle cramps, shallow breathing, increased respiratory rate, irregular heartbeat, agitation, headaches and decreased concentration. Surprisingly, educational attainment and literacy levels were higher for children who were conceived during periods of elevated temperatures. Included Extreme Temperature studies are outlined in Table 2.1 below. For more details on these studies, please see Appendix B, Table 6.2.2.

Table 2.1: Extreme Temperature Included Studies

Author(s)	Study title	Health outcome(s) discussed in the study
Baker, 2020 [28]	Characterizing the contribution of high temperatures to child undernourishment in Sub-Saharan Africa	Nutrition and growth- undernourishment
Tusting et al., 2020 [29]	Environmental temperature and growth faltering in African children: a cross-sectional study	Nutrition and Growth - includes Stunting, Wasting, Underweight -- Increased temperatures were associated with a greater risk of wasting and underweight, but a decrease in stunting
Wilde et al., 2017 [30]	The effect of ambient temperature shocks during conception and early pregnancy on later life outcomes	Child literacy linked to heat exposure during conception and pregnancy
Egondi et al., 2015 [31]	Temperature Variation and Heat Wave and Cold Spell Impacts on Years of Life Lost Among the Urban Poor Population of Nairobi, Kenya.	Mortality (all-cause)
Wichmann, 2017 [32]	Heat effects of ambient apparent temperature on all-cause mortality in Cape Town, Durban and Johannesburg, South Africa: 2006-2010	Mortality (all-cause)
Faye et al., 2021 [33]	Impact of different heat wave definitions on daily mortality in Bandafassi, Senegal	Mortality (all-cause)
Scovronick, 2018 [34]	The association between ambient temperature and mortality in South Africa: A time-series analysis	Mortality (all-cause)
Asamoah et al., 2018 [35]	Is ambient heat exposure levels associated with miscarriage or stillbirths in hot regions? A cross-sectional study using survey data from the Ghana Maternal Health Survey 2007	Miscarriage or stillbirth

Bunker, 2017 [36]	Excess burden of non-communicable disease years of life lost from heat in rural Burkina Faso: a time series analysis of the years 2000-2010	Increase in NCD-YLL: Cardiovascular diseases, Digestive diseases, Genitourinary, Malignant neoplasms, Neuropsychiatric condition, Endocrine disorders
Helman and Benjamin 2020 [37]	Temperature anomalies affect violent conflicts in African and Middle Eastern warm regions	Violence and temp have both direct (seasonal) and indirect effects (migration results in more competition for resources)
Gates et al., 2019 [38]	Short-term association between ambient temperature and homicide in South Africa: a case-crossover study	Increase in homicide
Kim et al., 2019 [39]	Suicide and Ambient Temperature: A Multi-Country Multi-City Study	Suicide
Abed and Matzarakis 2017 [40]	Seasonal Regional Differentiation of Human Thermal Comfort Conditions in Algeria	Heat stress
Dapi et al., 2010 [41]	Heat impact on schoolchildren in Cameroon, Africa: potential health threat from climate change	Fatigue, Thirst, Headaches, feeling very hot, feeling very hot in the head, impaired concentration
Wright et al., 2019 [42]	Socio-economic, infrastructural, and health-related risk factors associated with adverse heat-health effects reportedly experienced during hot weather in South Africa.	Sweating, headache and nausea, weakness, fatigue and dizziness, muscle cramps, hot, dry and flushed skin, shallow breathing, irregular heartbeat, agitation and confusion, cold, pale and clammy skin, increased respiratory rate, fainting, weak rapid pulse, shock, decreased level of consciousness, seizures, cardiac arrest
Bishop-Williams et al., 2018 [43]	Understanding Weather and Hospital Admissions Patterns to Inform Climate Change Adaptation Strategies in the Healthcare Sector in Uganda	Increase in all hospital admissions
Lokotola et al., 2020 [44]	Temperature as a modifier of the effects of air pollution on cardiovascular disease hospital admissions in Cape Town, South Africa.	Increase in CVD hospital hospitalizations
Aissa 2019 [45]	Influence of Weather Conditions on the Onset of Spontaneous Pneumothorax in the Region of Sousse (Tunisia): Analysis of Time Series	Spontaneous Pneumothorax (SP)

Flooding and storms/cyclones:

Climate change is expected to worsen the impact of floods and storms. These types of changes often go hand-in-hand with temperature and precipitation fluctuations, including increasing incidences of storms that lead to flooding.

For research on storms, which was not a specific EWE we identified at the outset, but it became apparent that the type of data we were looking for would be reported in studies exploring specific health outcomes related to storms, we found five studies as outlined in Table 2.2 below. For more details on these studies, please see Appendix B, Table 6.2.3. In summary, our research found that the most significant negative health outcomes associated with cyclones were cholera, fatalities, increased risk of malaria infections, skin infections, measles, pneumonia and mental health disorders. Cyclones caused widespread damage, resulting in many residents being displaced and needing to relocate to shelters that lacked basic services. Additionally, there was disruption in water and electricity supplies, food insecurity, compromised neonatal care after destruction of the neonatal intensive care unit (NICU) and the inability to provide treatment for chronic conditions such as diabetes, tuberculosis and HIV.

Table 2.2: Included Storm Studies

Author(s)	Study title	Health outcome(s) discussed in the study
Lequechane et al., 2020 [46]	Mozambique's response to cyclone Idai: How collaboration and surveillance with water, sanitation, and hygiene (WASH) interventions were used to control a cholera epidemic	Cholera, Mortality
Devi, 2019 [47]	Cyclone Idai: 1 month later, devastation persists	Cholera, Mortality, Malaria, Skin infections, Measles, Pneumonia, Mental health disorders
Cambaza et al., 2019 [48]	Outbreak of Cholera Due to Cyclone Kenneth in Northern Mozambique, 2019	Cholera, Malaria
Calgaro et al., 2020 [49]	Neonatal Intensive Care Unit Evacuation and Care During a Natural Disaster: The Experience of Cyclone Idai in Beira, Mozambique	Inaccessible care; Disrupted care; exposure (hypothermia)
Pozniak et al., 2020 [50]	HIV continuity of care after Cyclone Idai in Mozambique	HIV care, disruption in reproductive health care

For flooding, we identified 26 studies that focused specifically on flooding (and not also on temperature) and extracted data from these studies as outlined in Table 2.3 (below). For more details on these studies, please see Appendix B, Table 6.2.1. In general, our research showed that flood events also disrupted services, care cascades, and chronic health treatments. The adverse health effects associated with flooding in Africa included an increase in hospitalizations, mortality (drowning, injuries and electrocution), flood-related stress, anxiety, post-traumatic stress symptoms, rise in intimate partner violence, childhood malnutrition (underweight and stunting), increase in disease prevalence (kidney disease, malaria, diarrhea, skin infections, typhoid, cholera, dysentery, acute respiratory infections, Schistosomiasis, Leptospirosis, hepatitis, Rift Valley Fever, scabies and Dengue virus infection). A few studies found that extreme heat resulted in adverse maternal and neonatal health effects. Interestingly, in one study (Abiona 2017), in-utero flood exposure was found to have a positive impact on birth weight and height. Flooding resulted in a disruption to healthcare services, food insecurity due to farmland inundation, negative impacts on livelihoods, damage to property/houses/infrastructure, displacement, disruption in school attendance, contamination of water sources with heavy metals or sewage and the inability to access clean drinking water. Vulnerabilities were identified specifically in children, the elderly and pregnant women.

Table 2.3: Precipitation/Flooding Included Studies

Author(s)	Study title	Health outcome(s) discussed in the study
Abu and Codjoe, 2018 [51]	Experience and Future Perceived Risk of Floods and Diarrheal Disease in Urban Poor Communities in Accra, Ghana	Diarrhea
Alexander et al., 2017 [52]	Hydrometeorology and flood pulse dynamics drive diarrheal disease outbreaks and increase vulnerability to climate change in surface-water-dependent populations: A retrospective analysis	Diarrhea in children <5, Dehydration
Adelekan and Fregene, 2014 [53]	Vulnerability of artisanal fishing communities to flood risks in coastal southwest Nigeria	Disease occurrences, drowning, eye problems resulting from smoking fish over wet wood during flood

Adeagbo et al., 2016 [54]	The effects of natural disaster on social and economic wellbeing: A study in Nigeria	Disease occurrence, Injuries
Elsanousi et al., 2018 [55]	Impact of the 2013 Floods on the Incidence of Malaria in Almanagil Locality, Gezira State, Sudan.	Increase OP hospital visits, Malaria
Atufu and Holt, 2018 [56]	Evaluating the impacts of flooding on the residents of Lagos, Nigeria	Increase in flood-related hospitalizations, Mortality
Di Baldassarre et al., 2010 [57]	Flood fatalities in Africa: From diagnosis to mitigation	Mortality (all-cause)
Rieckmann et al., 2018 [58]	Exploring Droughts and Floods and Their Association with Cholera Outbreaks in Sub-Saharan Africa: A Register-Based Ecological Study from 1990 to 2010	Cholera
Tandlich et al., 2016 [59]	A Case Study on the Health Risks Related to Flood Disasters in South Africa	Cholera, Fungal respiratory infections
Boyce et al., 2016 [60]	Severe Flooding and Malaria Transmission in the Western Ugandan Highlands: Implications for Disease Control in an Era of Global Climate Change.	Malaria
Emmelin et al., 2008 [61]	Vulnerability to episodes of extreme weather: Butajira, Ethiopia, 1998 - 1999	Malaria; Diarrheal disease; Mortality
Adams and Nyantakyi-Frimpong, 2021 [62]	Stressed, anxious, and sick from the floods: A photovoice study of climate extremes, differentiated vulnerabilities, and health in Old Fadama, Accra, Ghana	Acute anxiety, Chronic stress, Disrupted sleep, Physical exhaustion, Mental distress
Taukeni et al., 2016 [63]	Post-traumatic stress disorder amongst children aged 8-18 affected by the 2011 northern-Namibia floods	Post-traumatic stress disorder (PTSD)
Okaka and Odhiambo, 2019 (a) [64]	Health vulnerability to flood-induced risks of households in flood-prone informal settlements in the Coastal City of Mombasa, Kenya	Stress/Anxiety, Mortality, General ill-health
Okaka and Odhiambo, 2019 (b) [65]	Household's perception of flood risk and health impact of exposure to flooding in flood-prone informal settlements in the coastal city of Mombasa	Stress/Anxiety, Malaria, Diarrhea, Skin infections, Typhoid Acute respiratory infections, Fever, Headache, Coughing,
Olanrewaju et al., 2019 [66]	Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management	Typhoid fever, Malaria, Skin rashes, Leptospirosis, Hepatitis A, Hepatitis E, Schistosomiasis, Cholera, Dysentery
Makanga et al., 2019 [67]	Place-specific factors associated with adverse maternal and perinatal outcomes in Southern Mozambique: a retrospective cohort study	Negative maternal and fetal outcomes Perinatal concerns
Abiona 2017 [68]	Adverse Effects of Early Life Extreme Precipitation Shocks on Short-term Health and Adulthood Welfare Outcomes	Wasting, Stunting
Lopez-Carr et al., 2016 [69]	Climate-Related Child Undernutrition in the Lake Victoria Basin: An Integrated Spatial Analysis of Health Surveys, NDVI, and Precipitation Data.	Undernutrition, Stunting
Bryson et al., 2021 [70]	Seasonality, climate change, and food security during pregnancy among indigenous and non-indigenous women in rural Uganda: Implications for maternal-infant health	Maternal health and food insecurity (nutrition)
Zamand and Hyder 2016 [71]	Impact of climatic shocks on child human capital: evidence from young lives data	Nutritional status, body mass, learning outcomes

Sara et al., 2018 [72]	Scabies Outbreak Investigation and Risk Factors in East Badewacho District, Southern Ethiopia: Unmatched Case Control Study	Scabies
Nosrat et al., 2021 [73]	Impact of recent climate extremes on mosquito-borne disease transmission in Kenya	Dengue, Malaria
Gudo et al., 2016 [74]	Serological evidence of rift valley fever virus among acute febrile patients in Southern Mozambique during and after the 2013 heavy rainfall and flooding: Implication for the management of febrile illness.	Rift Valley Fever
Ahmed et al., 2018 [75]	Preliminary investigation of flooding problems and the occurrence of kidney disease around Hadejia-Nguru wetlands, Nigeria and the need for an ecohydrology solution	Chronic Kidney Disease
Cools et al., 2020 [76]	Rainfall shocks and intimate partner violence in sub-Saharan Africa	Intimate partner violence

For research where studies looked at health-related outcomes in settings where temperature and precipitation EWEs took place at the same time, or overlapped, we found 26 studies as outlined in Table 2.4 below. For more details on these studies, please see Appendix B, Table 6.2.**4.** When both EWEs (i.e., flooding/heavy rains and high temperatures) were studied in combination, the adverse health effects noted included an increase in cholera outbreaks, malaria incidence, infant and adult mortality, diarrheal diseases (rainfall having a greater impact), meningitis, anaemia, flu-like symptoms, Rift Valley fever outbreaks (above-normal rainfall having a bigger impact), Chikungunya, lower infant birth weights and stunting. For children, it was found that higher temperatures *in utero*, particularly during the first and third trimesters, and wetter conditions during the third trimester, are positively associated with severe stunting, though stunting decreases with temperature in early life. Additionally, extreme temperatures were found to disrupt healthcare services when energy usage exceeds local capacity, food insecurity, a rise in violent conflicts, decrease in diet diversity (more strongly linked to extreme temperatures).

Table 2.4: Extreme Temperatures and Precipitation Included Studies

Author(s)	Study title	Health outcome(s) discussed in the study
Codjoe et al., 2020 [77]	Impact of extreme weather conditions on healthcare provision in urban Ghana.	Access to care disrupted; care facilities damaged; carers and patients exposed to extreme heat; infrastructure damage
Maystadt et al., 2015 [78]	Local warming and violent conflict in North and South Sudan	Temperature and rainfall shocks correlate with increased violence
O'Loughlin et al., 2014 [79]	Effects of temperature and precipitation variability on the risk of violence in sub-Saharan Africa, 1980-2012	Increase in conflicts, Violence against civilians
Meierrieks 2021 [80]	Weather shocks, climate change and human health	Mortality (infant and adult)
Azongo et al., 2012 [81]	A time series analysis of weather variability and all-cause mortality in the Kasena-Nankana Districts of Northern Ghana, 1995-2010	Mortality (all-cause)
Diboulo et al., 2012 [82]	Weather and mortality: a 10-year retrospective analysis of the Nouna Health and Demographic Surveillance System, Burkina Faso	Mortality (all-cause)
Egondi et al., 2012 [83]	Time-series analysis of weather and mortality patterns in Nairobi's informal settlements.	Mortality (Non-accidental deaths- HIV/AIDS-related mortality, including tuberculosis, cancer, hypertension, diabetes, and other NCDs, pneumonia, acute infections

		(meningitis, measles, malaria, and other acute infections))
Randell et al., 2020 [84]	Stunted from the start: Early life weather conditions and child undernutrition in Ethiopia	Stunting (HAZ)
Grace et al., 2021 [85]	Exploring Strategies for Investigating the Mechanisms Linking Climate and Individual-Level Child Health Outcomes: An Analysis of Birth Weight in Mali	Birth weight affected by malaria, heat, and precipitation
MacVicar et al., 2017 [86]	Whether weather matters: Evidence of association between in utero meteorological exposures and foetal growth among Indigenous and non-Indigenous mothers in rural Uganda.	Lower birth weights
Grace et al., 2015 [87]	Linking climate change and health outcomes: Examining the relationship between temperature, precipitation and birth weight in Africa	Maternal outcomes and birthweight
Colon-Gonzalez et al., 2016 [88]	Assessing the effects of air temperature and rainfall on malaria incidence: An epidemiological study across Rwanda and Uganda	Malaria, Anaemia
Ayanlade et al., 2020 [89]	Early warning climate indices for malaria and meningitis in tropical ecological zones.	Malaria, meningitis
Chuang et al., 2017 [90]	Assessment of climate-driven variations in malaria incidence in Swaziland: toward malaria elimination.	Malaria
Chirebvu et al., 2016 [91]	Clinical Malaria Transmission Trends and Its Association with Climatic Variables in Tubu Village, Botswana: A Retrospective Analysis.	Malaria
Mrema et al., 2012 [92]	The influence of weather on mortality in rural Tanzania: a time-series analysis 1999-2010	Rainfall anomalies drive malaria incidence
Dunn and Johnson 2018 [93]	The geo-spatial distribution of childhood diarrheal disease in West Africa, 2008-2013: A covariate-adjusted cluster analysis	Diarrhea
Thiam et al., 2017 [94]	Association between Childhood Diarrhoeal Incidence and Climatic Factors in Urban and Rural Settings in the Health District of Mbour, Senegal	Diarrhea
Heaney et al., 2019 [95]	El Nino-Southern oscillation and under-5 diarrhea in Botswana	Diarrhea
Horn et al., 2018 [96]	Association between Precipitation and Diarrheal Disease in Mozambique.	Diarrhea
Azage et al., 2017 [97]	Effect of climatic variability on childhood diarrhea and its high-risk periods in northwestern parts of Ethiopia.	Diarrhea
Ikeda et al., 2019 [98]	Climatic Factors in Relation to Diarrhoea Hospital Admissions in Rural Limpopo, South Africa.	Diarrhea hospital admission among children <5 when wetter or drier than normal conditions are present. Rainfall is correlated with disease transmission
Olago et al., 2007 [99]	Climatic, Socio-economic, and Health Factors Affecting Human Vulnerability to Cholera in the Lake Victoria Basin, East Africa	Cholera
Niles et al., 2021 [100]	Climate impacts associated with reduced diet diversity in children across nineteen countries.	Reduced diet diversity
Apantaku et al., 2013 [101]	Climate change and rural households' health in Ijebu Northeast area of Nigeria.	Common cold, Rashes, Malaria, Fever, Cough
Anyamba et al., 2012 [102]	Climate Teleconnections and Recent Patterns of Human and Animal Disease Outbreaks	Chikungunya and Rift Valley Fever

Drought:

The scoping review of drought identified 15 studies (see [22]). Drought was found to be associated with a range of negative health outcomes, which we broke down into three categories: (1) drought and adverse nutritional health including malnutrition resulting in reduced body size, malnutrition resulting in wasting, stunting and underweight, mortality from food insecurity, anaemia from food insecurity and nutrition-related disability from food insecurity; (2) drought and diseases due to microbial contamination of water including cholera outbreaks, diarrhoeal diseases, scabies outbreaks, vector-borne disease outbreaks and malaria-related mortality; and (3) drought and health behaviours including HIV prevention and care behaviours [22].

In the first category - drought and adverse nutritional health - the prevalence of malnutrition and childhood disability was found to be higher in boys compared to girls. Children under the age of 5 years were found to be more susceptible to drought-related food insecurities, resulting in underweight, stunting and wasting. There was a higher risk of adverse nutritional health in children who had diarrhoea and acute respiratory infection. The risk of children having anaemia was found to be higher in areas with a high malaria burden and associated with poor socioeconomic status, stunting, age <36 months and household head educational status. Contextual factors which were found to be protective included phone ownership, agricultural and nutritional initiatives, improved access to water and sanitation, presence of the mothers in the households and mothers' education.

In the second category – drought and diseases due to microbial contamination of water – a decrease in water availability due to drought results in poor hygiene practices and a decrease in water quantity and quality. Subsequently, an increase in the incidence of cholera and diarrheal diseases was evident. Drought was also found to create favourable breeding environments for various vectors, thereby increasing the occurrence of vector-borne diseases, including dengue outbreaks. Children and young adults were found to have a higher risk of developing scabies compared to adults, with over 75% of cases having a family member who was affected. Better preparedness in drought-affected regions was found to reduce disease incidence.

In the third category- drought and health behaviours-females were found to be more vulnerable to the effects of drought. Females were more likely to engage in selling sex and to experience forced sex. Additionally, the prevalence of HIV in drought-affected communities was found to be higher in females. While this category only had one study included, it is a vital topic to explore in regions such as South Africa, which already has a high HIV/AIDS burden.

Table 2.5: Drought Included Studies

Author(s)	Study title	Health outcome(s) discussed in the study
Bauer and Mburu, 2017 [103]	Effects of drought on child health in Marsabit District, Northern Kenya	Malnutrition
Belay et al., 2017 [104]	Estimating the household drought-driven food insecurity using system dynamics model: The case of Afar national regional state of Ethiopia	Malnutrition
Lazzaroni and Wagner, 2016 [105]	Misfortunes never come singly: Structural change, multiple shocks and child malnutrition in rural Senegal	Malnutrition
Kinyoki et al., 2016 [106]	Assessing comorbidity and correlates of wasting and stunting among children in Somalia using cross-sectional household surveys: 2007 to 2010	Wasting, underweight and stunting in children
Kinyoki et al., 2017 [107]	Conflict in Somalia: impact on child undernutrition	Wasting, underweight and stunting in children
Delbiso et al., 2017 [108]	Drought and child mortality: a meta-analysis of small-scale surveys from Ethiopia	Under-5 death rate (U5DR)
Gari et al., 2017 [109]	Anaemia among children in a drought-affected community in south-central Ethiopia	Anaemia

Dinkelman, 2015 [110]	Long-run health repercussions of drought shocks: evidence from South African homelands	Prevalence of disability
Rieckmann et al., 2018 [58]	Exploring Droughts and Floods and Their Association with Cholera Outbreaks in Sub-Saharan Africa: A Register-Based Ecological Study from 1990 to 2010	Cholera outbreaks
Alexander et al., 2013 [111]	Climate change is likely to worsen the public health threat of diarrhoeal disease in Botswana	Diarrhoeal disease
Bandyopadhyay et al., 2012 [112]	The impact of rainfall and temperature variation on diarrhoeal prevalence in Sub-Saharan Africa	Diarrhoeal disease
Enbiale and Ayalew, 2018 [113]	Investigation of a Scabies Outbreak in Drought-Affected Areas in Ethiopia	Scabies outbreak
Anyamba et al., 2014 [114]	Recent weather extremes and impacts on agricultural production and vector-borne disease outbreak patterns	Dengue outbreak, Rift Valley fever
Bakshi et al., 2019 [115]	Exploring the link between climate variability and mortality in Sub-Saharan Africa	Malaria-related mortality
Low et al., 2019 [116]	Association between severe drought and HIV prevention and care behaviours in Lesotho: A population-based survey 2016-2017	HIV status and HIV health-related behaviors

2.5 DISCUSSION

Extreme weather events in South Africa

The rise in greenhouse gas emissions is predicted to cause a more than 6°C rise in temperatures over the northern, central and western parts of South Africa [117]. The rise in temperature, accompanied by the decrease in precipitation events, is expected to cause more frequent and intense drought episodes [118]. This has already occurred in both the Eastern and Western Cape where extreme water shortages have challenged not only local services delivery, and governance [119-121], but also health. Changes in rainfall are also reported to significantly impact the onset and length of the Kwa-Zulu Natal midlands' fire seasons [122]. Heavy rainfall and thunderstorms, occurring in the Highveld region, resulted in flash floods. The north-eastern parts of South Africa are vulnerable to flooding due to tropical cyclones, e.g., cyclone Eline, which occurred in 2000, caused flooding in South Africa, Mozambique, Zimbabwe and Botswana [123]. Our research indicates the need to develop an HVI framework for EWE that takes into account the already robust Climate Risk and Vulnerability Assessments (CRVA) in place and validated for South Africa (see the Greenbook; https://riskprofiles.greenbook.co.za). As such, our HVI framework/indicators should be used alongside and with available, context-specific CRVAs.

The results from the scoping review provided us with an overarching view of the adverse health outcomes associated with EWEs. It became evident that these health outcomes are not merely a direct consequence of exposure to an EWE. Exposure in itself can have direct and devastating impacts on individuals. However, the research showed that social, biological, environmental, societal and governmental factors can directly and indirectly influence the health of those affected by EWEs. The evidence scoping we have undertaken points to the following necessary questions to begin the collaborative development of an HVI framework:

1. Engage in mapping of the local area with regard to recent EWEs – what happened? (i.e., standing water, stormwater)
2. Checklist of experiences and exposures – cumulative count of checks as an indicator of pre-determined vulnerabilities (proximity to river, to firebreak, to unmanaged forest/veld, housing structure materials)
3. Gathering data on vulnerabilities of EWEs from lived experiences, not otherwise presented in available evidence

In workshops, we were able to gather evidence for points 2 and 3 above. This evidence was combined with the final checklist of evidence-based results from the scoping review to develop a detailed HVI framework that can be workshopped and used in various local contexts in combination with points 1 and 2 outlined above (see Chapter 4). We have started by engaging with sites known to have experienced each of the EWEs, so that our testing of the HVI indicators is relevant to that experience, but determining which set (or sets) of EWE-specific indicators should be used in any given site depends on point 1 in combination with existing CRVAs.

CHAPTER 3: HEALTH VULNERABILITY LITERATURE REVIEW

3.1 INTRODUCTION

Concurrent with the systematic review we undertook to understand the health outcomes related to EWEs, we drew from the systematic search those studies that did not fit our inclusion criteria, but were relevant to the project's larger aim of developing an HVI for EWEs. In other words, there was ample research that may not have directly addressed specific health outcomes related to EWEs, but still addressed some aspect of human health and EWEs. The literature review below focuses heavily on African resources and research, but does draw in some research from other regions – particularly where research was unavailable on a topic on the African continent/region. This review is broken into four parts, touching on topics and highlighting areas of pertinence to the project's larger questions. It starts with providing:
1. A general background on climate change, extreme weather events and human health
2. A few notes on EWEs in South Africa
3. A brief literature review on vulnerability studies
4. Current literature on health vulnerability

This literature review represents a second component in our multi-layered approach to developing the draft framework. The research team engaged with this literature as part of the larger workshopping process (described in more detail in Chapter 4) to develop the framework.

3.2 GENERAL BACKGROUND: CLIMATE CHANGE, EXTREME WEATHER EVENTS AND HUMAN HEALTH

Climate change is happening with potential life-shaping impacts, and human activity accelerates these changes; for example, as outlined by Mordecai et al [124], the long-established concern of malaria in many parts of sub-Saharan Africa could give way to arboviruses as disease burdens shift, which then incur knock-on impacts for decision-making around public health expenditures and attention. Concerns for such accelerating shifts go hand in hand with increasing incidences and severity of extreme weather events, all of which influence human health [125-127] and public health generally [128] but especially South Africa's healthcare system [129]. Research shows that climate change and extreme weather events will likely shift burdens of disease and country-specific disease profiles [124]. At the same time, the increase in EWEs will add burdens to already strained healthcare systems, and healthcare workers (see [130]). Relatedly, these connections between disease burdens, historic vulnerabilities and injustices, paired with current environmental and social vulnerabilities, illustrate Rouf and Wainright's [131] efforts to link social, climate and health justice.

The rate and power of extreme weather events are increasing regionally [132] and globally [133], and with them, impacts on human health, particularly as these events lead to coastal damages, including flooding (see [134]) and temperature extremes. Globally, these extreme weather events directly influence health outcomes [133], although a paucity of research means there is limited epidemiological evidence for this association in Africa [135]. In West Africa, for example, Codjoe reflects on the lack of region-specific evidence from which to develop plans for adapting health services to climate change and the lack of evidence base from which to draw locally context-specific lessons [77]. However, recent events like Cyclones Idai and Kenneth (see [136]) in Mozambique, and floods in Khartoum [137] or more locally, in Port Elizabeth [138] or KwaZulu-Natal and droughts in the Western and Eastern Cape can provide important lessons learned. For example, Hierink et al [136] shed light on lessons learned from Cyclones Idai and Kenneth, which highlighted opportunities for improvement in health care delivery systems and integrating accessibility modelling in early disaster response to inform discussions on health system preparedness, response and recovery. These lessons learned from climate shocks, disasters and extreme weather events should not be forgotten as they can offer helpful guides [139]; informing decision-making – not just regarding health – for policy makers and citizens alike. This research project keeps its focus on citizens, with the aim of offering an easy-to-use framework to explore one's health vulnerability when facing EWEs.

Climate change, and relatedly extreme weather events, have direct and indirect impacts on human health. Direct impacts documented in southern Africa include those resulting from EWEs, including flood, heat, wind, and drought, which influence vector-borne disease outbreak patterns [114, 140]. For example, increased temperatures and rainfall pattern changes impact on diarrheal diseases, like Cholera, as seen in Sara et al's [141] work in Tanzania. Flooding events and storms can lead to disruptions and delays in care or inaccessible services [142], for example, impacting pregnancy outcomes [143, 144] and chronic care access. Extreme heat has been the focus of a review to understand its influence on the risk of preterm birth, low birth weight, and stillbirths [145], and has been found to influence childbirth timing [146]. At the same time, while heat extremes pose multiple human health threats in South Africa, so do cold extremes, as argued by van der Walt et al [147] in their trend analysis of cold extremes.

Temperature increases, including longer-term higher temperatures or single days of extreme temperatures, are understood to become more widespread sooner than previously expected [148] and have multiple human health impacts, ranging from cardiac outcomes in general [149], and specifically myocardial infarction [150, 151] to violent interactions/increases in violence [152, 153] to listeriosis outbreaks [154] to changes in seasonal allergies [155]. Higher environmental temperatures may not only increase prevalence, but also accelerate the onset of some glaucomas [156]. Additionally, colder average temperatures, or cooling in general, is shown in various parts of the continent to impact vulnerable groups, including children under five years, women and the elderly more than others (for example, higher mortality among these groups is seen in Ghana [157]). This is true for temperature shifts in general. In this way, extreme temperatures, both hot or cold, that are anomalous to localities, are known to impact health and wellbeing, from diarrhoeal disease to mental health concerns (see, for example [158], in the US, where mental health ER visit rates are being studied). At the same time, drought has been shown to increase intimate partner violence [159], put pressure on food systems, influence nutrition and prenatal outcomes, among many other health outcomes (see [22]). Temperature changes in general can influence numerous aspects of human wellbeing, including stunting in children (see [84]). Similar impacts are seen during drought, for example, in the relationship between greater rainfall and underweight/wasting among children in Uganda [160]. In other words, sudden rainfall reductions are likely to have acute adverse effects on a child's access to nutrition.

Extreme rainfall events can lead to soil saturation during previously dry periods – this may in turn lead to habitat changes which allow for viruses like Rift Valley Fever (RVF) to proliferate (see, for example, Williams et al [161]). These types of indirect impacts also include shifts to ecosystems that, for example, weather extremes have been found to impact agricultural production [114], and specifically, weather shocks in Mozambique, impact agricultural markets [162], thereby influencing nutrition; and resulting in chain reactions – for example, a combination of food and water insecurity, population growth, poverty and climate shocks may increased dependency on environmentally tolerant plants with neurotoxic potential - leading to the reality that undernourished people who ingest plants with neurotoxic potential may trigger acute encephalopathy (lychee, ackee fruits), sub-acute spastic paraparesis (grasspea, cassava root/leaves) or ataxic neuropathy (cassava root flour) [163]. Floods can lead to displacement, which is known to influence civil conflict [164] and disproportionately impact those living with extreme socio-economic constraints [165]. Water-related concerns like drought or shocks in rainfall events are similarly known to increase conflicts [166] and post-traumatic stress [167-169].

Research at the intersection of human health and climate change highlights the seasonal fluctuations in virus and flu experiences [170] may increase or be felt more acutely as extreme weather events increase. Similarly, associations between diarrhea and climate change [171] are likely to increase with increasing temperatures and periods of extremes, as projected in Botswana, for example, by Alexander et al, 2013 [111]. Host-parasite relationships are expected to be altered, and in some cases, as with some snails (schistosome species), temperature increases (up to a certain point) have been shown to increase their reproduction (see [172, 173]). Subsequently, climatic shifts, including extreme events, impact the geographical distribution of schistosomiasis as seen in Zimbabwe [174] and China (see [175, 176]). Relatedly, some malaria research suggests that elevated temperatures (heat shock) may select for insecticide-resistant mosquito hosts (see [177]).

Extreme weather events (EWEs) have been shown to disproportionately impact those already vulnerable, including people with disabilities [178], or those already living in resource and economically strained areas [165, 179] or migrant and displaced populations [180]. This is not unique to southern Africa; in fact, disparities in access to care

and in health outcomes along demographic and socio-economic lines after hurricanes for example, are well documented in the United States [179, 181] and among children facing climate disasters in India (see [182]). In this way, EWEs are set to magnify already existent environmental injustices and health inequalities (see [183, 184]). Planning, knowledge and awareness are important efforts to address potential risks. In Madagascar, Mohan et al [185], suggest that Cyclone Haruna may have devastated healthcare service delivery with significant negative human health outcomes, but efforts in place to build resilience among neighbourhoods, like the provision of backup services, seem to have led to some protective efforts.[1] Environmental health practitioners have played a critical role in monitoring health in relation to the human environment, but now must be brought into the development of adaptation strategies, including 'measures to protect communities against the challenges of climate variability at a grassroots level' [125]. This means, one key priority is to limit the disruption of healthcare services and delivery, and at the same time, highlights a good indicator of vulnerability – that is, disruptions to healthcare services (and delivery).

Globally, attention to the impacts of the intersection between climate change, extreme weather events and human health are increasing. In Mexico, research unpacks the acute infectious disease associated with catastrophic climate events and warming [186]. In Ethiopia, a review of climate change and health research provides some insights into gaps in understanding [187]. Bryson et al [188] conducted a scoping review of neglected tropical diseases in the context of climate change for East Africa, while Ngutor [189] has explored the implications of recurring flash floods on Nigeria's public health system. Borg et al [190] conducted a scoping review exploring the impacts and adaptation strategies at the intersection of climate change and health in low- and middle-income urban informal settlements and suggested that research on the topic is limited and further well-designed studies are needed. Rataj et al's [191] systematic review explored extreme weather events in developing countries and related injuries and mental health disorders, while Rother et al [192] are in the process of a systematic review exploring extreme weather events' impacts on Sub-Saharan African child and adolescent mental health. Schmitt et al [193] conducted a scoping review exploring economic evaluations of health impacts of EWEs (which they referred to as Weather-Related Extreme Events).

Despite the fact that, increasingly, attention is being paid to the interface between EWEs and human health, there are some major gaps in understanding. For example, thresholds for temperature and weather variables are not aligned globally [194]; such standardization [195] and critical appraisals of this kind of research (environmental epidemiology) are only just starting to develop (see [196-198]). At the same time, there is much debate around the appropriateness of predictions around warming and extreme weather impacts on human health (see [199]) that highlights some key challenges in efforts to quantify the impacts of EWEs. With the realisation that climate change and extreme weather events influence a range of public health efforts and outcomes, there is acknowledgement that care in practice may have to shift as well. This was made clear through research done by Ephraim et al [200] which indicates that climate variation changes biochemical markers of kidney disease. Living through extreme weather events, and the human health impacts of such experiences, from mental health (including long-term impacts) [201] to understanding the moulds and fungi that grow after a flooding event or hurricane (like Sandy) and how these impact on wellbeing (see [202]) are emerging topics that require attention. The impacts of climate change on water quality are often considered, but less often discussed is the intersection of climate extremes and groundwater. Fantong et al [203] have explored how climate change is implicated in groundwater-derived methemoglobinemia and fluorosis in one region in Cameroon, but more studies of this nature that address seasonal fluctuation in deep aquifers are critical. This type of thinking, linking seasonal fluctuations with underground water science, and human health studies (e.g., epidemiology), requires transdisciplinary efforts [204]. Increasingly, mixed methods approaches are being used to understand the interconnections between extreme weather events and human health (see [205]), including the importance of citizens' understanding of these events. More discussion on the need for transdisciplinary and mixed methods considerations is outlined in Chapter 4.

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[1] The authors suggest: "Maintenance of routine health care services, coupled with the provision of additional services and health education where needed, enabled those in need to access food, shelter and support for rebuilding their homes, and served to limit the impact of the cyclone. Communities could thus resume normal functioning more quickly. In spite of the devastating impacts of Haruna, the authors believe that by working cooperatively to respond to this extreme weather event and in resuming their normal activities as quickly as possible, these communities were clearly exhibiting community resilience."

3.2.1 EWEs In South Africa

As previously mentioned in Chapter 2, rising emissions are predicted to cause a more than 6°C rise in temperatures over the northern, central and western parts of South Africa [117]. At the same time, increasing temperatures, accompanied by reduced precipitation events will likely result in more frequent and intense drought episodes [206]; already the case in the Western Cape, which faced extreme water shortages from 2015 to 2018 [207]. Rainfall changes are suggested to have impacted Kwa-Zulu Natal midlands' fire seasons [122]. The north-eastern parts of South Africa are vulnerable to flooding due to tropical cyclones; e.g., cyclone Eline, which occurred in 2000, caused flooding in South Africa, Mozambique, Zimbabwe and Botswana [123]. Despite these increasing EWEs, Cherisch et al's 2019 [117] case study on the South African health sector's role in adapting to climate change suggests that while several climate change policy frameworks have been developed at national and local government levels, there are some shortfalls when considering vulnerable groups, occupational settings and health care worker training/curricula. This case study suggests that while systems forecasting of EWEs and surveillance around malaria are well established, policies and practices "pay little attention to health concerns and the specific needs of vulnerable groups, and there is little evidence about the country's preparedness for EWEs, or the ability of the already strained health system to respond to these events" [117]. As noted earlier in this chapter, the project aims to combine citizen input with available evidence to develop a useful framework; in practice this means transparently discussing the influences of the framework (as offered in Chapter 4), testing the framework (initiated, as described in Chapter 4), and using that feedback to rework the tool (as reported in Chapter 4). While these efforts have been initiated in southern Africa (Cape Town, Pietermaritzburg and Harare), this process is nascent, and further research would be required to confidently offer a framework without acknowledging the need for further workshopping and development.

3.3 VULNERABILITY STUDIES

There exists a plethora of studies assessing vulnerability from a diversity of perspectives and angles. Cutter et al [208] provide an exhaustive overview of the research in this field prior to 2009. Since then, studies range from research that focuses on spatial analysis that models biophysical and social vulnerabilities to specific EWEs like flooding (see, for example, [209]) to those that explore the vulnerabilities associated with socio-economic status and heat risk (see [210]). In between are studies that explore social vulnerabilities to shocks more generally [211] by looking at flood events in Mozambique, or those that identify specific weather events, like flooding, without focusing on health, in Zimbabwe (see [212]), or those that unpack the vulnerabilities of living in specific types of ecosystems where health concerns arise, as Isunju et al (2016) [213] have been done for those living in informal dwellings on wetlands in Kampala, Uganda. While the focus of types of events or intersecting concerns (health, poverty, livelihoods) varies in the studies above, so do the scales of these assessments. Dintwa et al [214] focus on the district level, creating a district social vulnerability index (DSVI), while many spatial analyses focus on regions, and yet others like Belle et al [215] focus on specific villages or comparisons between villages. Skjeflo et al [216] highlight the importance of understanding vulnerability at the household level.

In fact, even in the context of South Africa specifically, literature reviews have highlighted that while climate and vulnerability risk assessments (CRVAs) abound (see [217, 218]), such assessments are specific to the vulnerabilities and outcomes they focus on, and these vary greatly between assessments. As such, a South Africa-specific vulnerability index, focused on health concerns, is relevant and salient, as there is a gap in research at the intersection of EWEs and human health impacts. We undertake a contribution to that effort here, focusing first on the literature that emerged from our search around vulnerability studies, and then unpacking those that are most locally relevant with regard to EWEs, both in the region (geography and resources) and particular focus (human health).

Earlier work, in the 1990s and at the turn of the century, indicates the importance of considering vulnerable groups in vulnerability assessments, noting that social vulnerability in many cases goes hand in hand with environmental vulnerability (see [208, 219-224]). Additionally, certain groups (for example, women; see [225, 226]) and locations

(regions, neighbourhoods, etc, see [227]) are more at risk of feeling the greatest impacts of disasters and extreme weather events. While these earlier works are, in many cases, two decades old, current work still draws on these methods and modes of analysis; for example, see Dintwa et al's work drawing on the Cutter model [228] in Botswana.

As extreme climate events impact all aspects of life, especially among people who rely on natural resources for their livelihoods and sustenance, risk and vulnerability assessments that explore, for example, livelihood vulnerabilities (see, for example [229]; or for work done in Malawi, see [230]) are important to consider when exploring health vulnerabilities, however, without a dedicated focus on health-related experiences, these indices are useful, but do not provide enough information. Extreme weather events may influence livelihoods, especially in rural areas in low- and middle-income countries (see Niyibizi 2013 [231] for an assessment of vulnerability indicators relevant to rural areas in developing countries) where resource access is disrupted, but so are other ways of living. This is particularly poignant, for example, in mountainous areas facing 'climate hazards' as a result of extreme weather events, and as such, Tyubee et al's (2014) [232] work in Nigeria can be important to consider. Both studies highlight the importance of context, and why these frameworks and assessments must be context-specific, while Niyibizi et al [231] also indicates the importance of layering vulnerability and risk assessments.

Vulnerability research specific to weather shocks, or extreme weather events, exists. For example in Ethiopia and Nigeria, Nwaka and Akadiri's (2020)[233] comparative research highlighted that across countries, there are major differences in the gendered experiences related to food insecurity post-drought or flood. Their work drew on both experiences and perceptions surveys, but was not limited to this as a mode of analysis (Nwaka and Akadiri 2020) [233]. In Lwasa (2018)[234] a community survey and resident input are paired with GIS spatial analysis to understand drought and flood risk, impacts, and adaptation options in the rural Ugandan area of Pallisa; a household asset survey was one methodological tool used in this study. In Burkina Faso, Dos Santos et al (2020) [235] analysed factors associated with becoming a 'disaster victim' for Ougadougo residents during a 2009 flooding event. While these studies can all be linked to health/wellbeing outcomes, they are not specifically focused on health vulnerability. In addition, these studies (Nwaka and Akadiri 2020; Lwasa 2018) and many others rely on GIS data (see [236] conference abstract based on research conducted in Malawi around flood risk, also in Malawi, see Mwale et al 2015 [237] and Dintwa et al's 2019 work in Botswana [228]; see also Zulkhairi et al [238] in Nigeria) and use some form of high-level mathematics, including modeling or regression analysis, to conduct their vulnerability assessments. This runs counter to the aims of our project, which intends to be local-resident user-friendly. Assessments do exist that draw on easier-to-use metrics or indicators, for example, Sowman [239] describes participatory and rapid vulnerability assessments used among small-scale fishers to support adaptation planning. Yankson et al's [240] research in Ghana, focused on flood vulnerability, draws on seven indicators including house location and physical characteristics; household and community flood adaptation; dwelling type; house and house environment; household socioeconomic characteristics and experiences and perceptions of flood risk; however, health components are not considered.

Relatedly, such layering of assessments provides for some buffer when forms of analysis and assessment might only focus on one EWE, or area of related concern (health, livelihood, etc). In other words, layering of assessments provides a more realistic picture of people's everyday lived realities, where EWEs do not happen in isolation, but more often in concert. To this end, researchers like Okpara et al [241] and Kamanga et al [242], explored climate-water conflicts as double exposures, and multi-hazard frameworks to assess flood and drought in combination, respectively, have begun to address overlapping concerns. This is also one key area of future research, and a central recommendation from the current report (see final chapter), is the need to consider the offered frameworks as part of a process of layered engagements (and tools) to assist in developing an understanding of the intersecting and variable realities around human health in the context of extreme weather events.

What is common in many vulnerability index studies is the acknowledgement that while indicators and indices are useful, they must be understood to be limited in that they often are unable to address the complexity of local-level vulnerability in detail (see [142, 240, 243]) or the highly differentiated local vulnerabilities [214]. At the same time, also widely acknowledged are the realities that one negative impact has long-ranging consequences and often

chain reactions, as suggested by Brereton et al [244] in their systems science approach that unpacks causal loops with regard to children's environmental health. Similarly, looking at causal chains and pathways, Zebisch et al [245] provide a standardized framework for climate vulnerability and risk assessment in their vulnerability sourcebook, which can provide some insights, but for our purposes, this resource is only useful as part of a larger effort to unpack not just causal relations, but on the ground, lived experiences. In this way, our work requires consideration first of existing climate risk and vulnerability assessments (CRVAs) and vulnerability indices (Vis) that can determine extreme weather-related risks, and then our framework asks specifically about the experiences and vulnerabilities of those EWEs with regard to human health. In this way, community-based and participatory-friendly metrics are necessary, but extremely difficult to find in the literature. Sowman [239] is one of the very few examples where such efforts have been undertaken; in this case, participatory and rapid vulnerability assessments were done among small-scale fishers to understand vulnerabilities and plan for adaptive responses. Although health emerged as a theme, it was not a focus of the vulnerability assessments in this case [239]; however, the rapid and participatory approaches are useful for our research efforts. Another vulnerability assessment process that is particularly useful towards the aims of our research is that undertaken by Bigi et al [246], specifically because in this research site's rural Kenyan context, there was limited data available. The reality of 'scant data' [246] is not unique to Kenya, and a key consideration in developing an index and framework that citizens can make use of for our research as well. It is important to remember that vulnerability indices are useful, but have many limitations; for example, Rufat et al [247] have called into question how valid they are. With this in mind, our work offers one of many approaches that should be layered to understand the lived reality for people through extreme weather events.

3.3.1   Health Vulnerability Indices

Health vulnerability indices are an emergent area of research, most notably in Brazil, particularly in the area of Belo Horizonte [248, 249], with less research available in India [250] and the US. On the African continent, these types of analysis are limited, but available, for example, in Sudan [251] and Ethiopia [252]. In general, these indices tend to consider exposure, adaptive capacity, and sensitivity in various permutations to determine a number $0 - 1$ that indicates the level of vulnerability. These analyses tend to rely on complex permutations and weightings that are not easily usable for laypersons with limited to no training. Our approach rather takes these factors into account (exposure, adaptive capacity, sensitivity) through a series of indicators and simple summations, dispensing with a weighting system, and allowing for layering of exposures such that the outcomes of one's own vulnerability assessment may vary from $-24 - 48$, with the higher the score, the greater the vulnerability.

In the African context, Abbas [251] suggests that key indicators for health vulnerability include: 1. Access to facilities; 2. Interruption of healthcare services; 3. Ownership/use of bed nets (however, for southern Africa, this is only relevant to malaria areas, and is not relevant to Cape Town); 4. Sanitation situation (latrines, sewered, etc); 5. Water access, and 6. Considerations of vulnerable groups (double burden). For our framework development purposes, we started with these as key indicators and developed some additional ones, drawing on both evidence available (review data) and our workshop feedback. In order to address this in workshops, we asked, among others, the following questions to assist in ascertaining issues:
- When you think about health, what makes you feel vulnerable?
- When you think of extreme weather events (name the one relevant to the context), what, if anything, about the experience impacts your health?

In the following sections, broken up by EWE, we outline the literature available on our topic that emerged from our systematic search. This is by no means an exhaustive review, but simply an indication of studies that emerged from the systematic process that are not used as part of the evidence assessments for the framework we offer.

3.3.2   Wildfire

Although our systematic scoping review ultimately found no studies of relevance with regard to wildfire, we do note some key information on wildfires, in addition to the reality that more research is needed on the intersection of

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human health outcomes and wildfires. Wildfires require three essential components to start, i.e., ignition source, oxygen and fuel. Climate change is said to affect all three components in various ways, including an increase in heat waves, droughts, lightning strikes and stronger winds [253]. This is expected to impact forest fire seasons, frequency, intensity and spread [254]. The direct health effects associated with wildfire exposures include burns, injuries, mental health concerns and mortality. Wildfire smoke exposure has been positively associated with mortality, decline in lung function, asthma exacerbation and lower respiratory tract infections [27]. Wildfire exposure poses substantial risks to the health of firefighters. These health risks include cardiovascular morbidity, respiratory effects and impacts on mental health [255]. Additionally, human exposure to air pollution from wildfires, specifically particulate matter, is expected to increase and is a public health concern [254] that requires more focused attention and research.

3.3.3 Drought

According to the United Nations World Water Development Report (2020) [256] studies predict that by the year 2050, 52% of the world's population will reside in water-stressed regions. This situation could be attributed to a rise in temperatures and a decrease in precipitation events, with more frequent episodes of drought [118] . In South Africa, the Eastern Cape has experienced decreasing trends in the overall amount of spring rainfalls, as well as the number of rainfall days since 1981 [120] . During 2015-2017, water availability in Cape Town became critically low, with reserves containing only 38% in 2017 [121] . By April 2018 dam water levels had dropped to 17% [119]. Drought has been associated with both direct and indirect adverse health effects.

As mentioned previously (see Chapter 2), our scoping review showed that the adverse health effects associated with drought could be classified into 3 main categories: (1) drought and adverse nutritional health including malnutrition resulting in reduced body size, malnutrition resulting in wasting, stunting and underweight, mortality from food insecurity, anaemia from food insecurity and nutrition-related disability from food insecurity; (2) drought and diseases due to microbial contamination of water including cholera outbreaks, diarrhoeal diseases, scabies outbreaks, vector-borne disease outbreaks and malaria-related mortality; and (3) drought and health behaviours including HIV prevention and care behaviours [22].

3.3.4 Floods, Flood Vulnerability and Indicator-based Approaches

Climate change is expected to worsen the impact of floods and storms. The severity of these flood impacts depends on various factors, including the velocity of and the depth of water [257] . The most common health effects associated with storms and flooding are physical injuries. Storms are also associated with poisoning (carbon monoxide and gasoline), gastrointestinal illnesses, skin infections, worsening diabetes, hypertension and long-term malnutrition [26]. Children living in flood-risk areas have a greater risk of being stunted compared to unexposed children [258] . Heavy rainfall and flooding can affect water and sanitation infrastructures, mobilizing waterborne pathogens and increasing the incidence of waterborne diseases [17]. Furthermore, Cruz et.al (2020) reported that flood victims were at a greater risk of experiencing long-term mental health problems when compared to individuals who had not experienced floods [259].

Flood Vulnerability

As the earth warms, frozen stores of water will influence water levels globally and floods are therefore more likely to occur. Flood vulnerability index research is not necessarily new, either. Adelekan [260] offers a reflection on the importance of social scientists engaging with flood vulnerability studies, drawing on the case study of a 2011 flood in Nigeria. The researcher examines social flood vulnerability and flood risk perception, highlighting the importance of social science analysis in addressing global change issues. Flood vulnerability has been assessed using a variety of approaches, from systems approaches focused on drivers [261] to spatial analysis and community mapping [262], to surveys [263] and even by focusing on flood impacts on livelihoods (in Ghana [264]). In Cape Town, in

the neighborhood where our own focus group was conducted, Sweet Home Farm, flood risk and vulnerability were the focus of Desportes' (2016) [265] case study to understand multi-stakeholder collaboration.

One flood vulnerability index emerges from Dos Santos et al's work in [235] in Burkina Faso, where researchers analysed factors associated with becoming a 'disaster victim' for Ougadougo residents during the 2009 flooding event. This work suggests that natural disasters magnify urban inequities particular to extreme poverty, such that factors like a lack of sanitation, and electricity were seen to be determinant factors, as such this team used indicators relevant to this assumption (i.e., sanitation, roadways, drainage, infrastructure) and gathered/assessed details like, formality of roads etc., service delivery, stormwater management as core indicators for flood vulnerability. Similarly, other researchers suggest the need for place-based ([209]in Ghana), and locally developed approaches ([212]in Zimbabwe) when exploring flood vulnerability. More recent flood vulnerability indexes include Karamoui 's (2021) "new flood vulnerability index" specific to the pre-Saharan region, that highlights the intersectoral nature of required flood responses and offers six components [266]: climatic, physiographic, land use, anthropogenic, economic and access to services as indicators for identifying priority mechanisms and sectors of flood vulnerability. While a number of studies unpack health-related concerns related to flooding, including the influence of flooding on drinking water [267, 268], less often discussed are specific health indicators related to flooding. Health vulnerability itself is even less often a focus, however Okaka and Odhiambo look specifically at this topic in Mombasa, Kenya among residents of informal settlements [269] (see also [65, 270]).

Indicator Based Approach
Okaka and Odhiambo [269] have assessed health vulnerability in terms of flood exposure, flood sensitivity, and flood adaptive capacity (these are typical areas of interest when it comes to vulnerability indexes, as outlined below in more detail in Chapter 4). In order to understand the extent of a household's vulnerability to flooding and the adaptation strategies used to deal with flooding events, this research team drew on the work of Adger (2006)[271] and Srikuta et al. (2015)[272] to devise a total score based on these three components. Similarly, Bambrink et al (2015) [142] assess specifically flood risks and human health outcomes in an informal settlement in Ethiopia, and suggest that indicators relevant to the local context include sanitation type, water source, socio-economic status (determined by going without something needed), doctor diagnosis, and health concerns are all key indicators, along with number of days spent sick, perceptions of risk for a specific hazard and perceptions of risk of a particular health outcome related to flooding or climate hazard. Lwasa et al [273] provided important considerations for both flood and drought risks that we drew on when developing our indicators as well. Another locally relevant study drawing on the indicator-based approach was Yankson et al's assessment of flood vulnerability in the Greater Accra Metropolitan area of Ghana [240]. Although not health-specific (again), this index includes seven components: dwelling type; house and household environment; household socioeconomic characteristics; experience and perception of flood risk; household and community flood adaptation strategies; house location, and physical characteristics. As such, our own development of indicators has drawn heavily on these approaches that undertake to understand household structures and locations, perceived risks (health and otherwise) as well as lived experiences related to health in the context of flood events.

3.3.5   Extreme Temperature (Heat and Cold), Temperature Vulnerabilities and Indicators

Globally, anthropogenically induced rise in temperatures over the last century has resulted in an increase in the frequency and intensity of heat waves [274] . Heat-related morbidity and mortality is commonly assessed using hospitalisation records, emergency room admission reports, medical complaints made during heat waves and mortality data measured by reported deaths occurring above a pre-determined temperature threshold [275]. Heat waves impact on morbidity and mortality in southern Africa [34] and globally [276]; and are associated with increased morbidity and mortality, with studies reporting a 0.9% increase in mortality rates with a 1 °C rise in ambient temperature over certain thresholds [117]. In Chicago, in 1995, a heat wave killed approximately 700 people, while in 2008, a heat wave killed more than 70 000 Europeans [277]. Studies have shown that the risk of heat-related mortality increases within the first three days following exposure to intense heat [278]. Elderly individuals have an increased risk of heat-related complications [279] due to impaired vasodilation, decreased

sweat production and blunted autonomic responses [280]. Females are more vulnerable to elevated temperatures due to decreased (relative to men) sweat production, thicker subcutaneous fat and a higher metabolic rate [281]. In many places around the world, existent vulnerabilities (i.e., gender, age) are magnified by heat stress and heat waves [279], this is particularly true in southern Africa where socio-economic vulnerabilities may translate into living in informal housing, or in heat islands in urban areas (i.e., less desirable locations) (see Wong et al for a discussion of heat islands and human health implications [282]).

Research exploring human health in relation to climate change and extreme weather events is growing, both locally [283] and globally [210]. Recent research on South African cities includes Nana et al's [284] attempts to better operationalise heat wave considerations among the City of Johannesburg's Environmental Health Department by unpacking 'issues of concern' and existing 'contradictions' for local healthcare practitioners in the absence of policies around heat waves and extreme heat days. Additionally, work on the forms of housing type in relation to extreme heat and heatwave events remains an important topic for the southern African context (see, for example, Scovronick 2012 [285]). Wright et al 2019 explore the question of heat vulnerability in a South African context [42] by drawing on Tran et al's [23] questionnaire used to examine household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. As with the flood indicators discussed above, this method comprised of multiple sections unpacked a range of indicators from 1) general household information; 2) household socio-economic factors and health status of each household individual; 3) living conditions and dwelling characteristics; 4) availability of community resources; 5) behavioural attributes and social ties; and 6) perceptions, awareness and attitudes on climate change and health. Drawing on a hierarchical, multi-level structure, the questionnaire developed by Wright et al and modelled after Tran et al helped us to model our own structured questions and related framework, including Likert-like self-assessments (for more information on similar methods, see [286]) related to heat events and human health.

CHAPTER 4: HEALTH VULNERABILITY FRAMEWORK DRAFTS AND METHODS

4.1 INTRODUCTION

As already noted, our research indicates the need to develop an HVI framework for EWE that takes into account the already robust Climate Risk and Vulnerability Assessments (CRVA) in place and validated for South Africa (see the Greenbook). As such, the draft HVI frameworks we offer here incorporate local engagement as well as the evidence from the scoping review. We have made some efforts to gather data on vulnerabilities of EWEs from lived experience, highlighting some areas not otherwise available in the evidence base. In order to ensure that HVIs are locally relevant, engagement with CRVAs alongside our own indicators is needed on a case-by-case basis to continue developing a detailed HVI framework that can be workshopped and used in various local contexts. Here, we provide the frameworks as they have been developed after one phase of engagement. We first provide some insights and literature relevant to the decisions we made, as a team, when framing these health vulnerability indicators.

4.2 METHODS AND APPROACH

There is momentum behind transdisciplinary efforts to address the intersection of human health outcomes and EWEs, with more and more teams exploring how this might be best done [204]. Mixed methods approaches are being used to understand human perceptions around climate change in relation to extreme weather events and human health (see [205]). This type of research, which draws on climate data alongside human perceptions, adds to a better understanding of the lived experiences of extreme weather events and their influence on human health. For example, research at this intersection highlights the importance of citizens' understanding of such events [205], to ensure that speedy responses and lessons learned are incorporated into immediate responses. Kamara et al [287] explored the notion of resilience in relation to climate-induced disasters and well-being in southern Africa. This mixed-methods systematic review mirrors other resilience work in suggesting that resilience capacities are bolstered by the synergistic effects of multiple layers of support [288, 289]. This work highlights the importance of using multiple fields to understand complex problems. Increasingly, calls for multi-disciplinary approaches to address hazards related to extreme weather events and human health are emerging, noting the importance of incorporating climate data, modelling, epidemiology, and on-the-ground experiences, to address concerns such as cholera (see [290]). As such, we have drawn on multiple disciplines and methods (reviews, interviews, focus groups) to develop the frameworks we offer.

4.2.1 Indicator Methods for Proposed HVI Framework Draft

After considering all the literature presented in the previous chapter (3) with the health outcomes we extracted from the scoping review (Chapter 2), we understood the need for context specificity (and thus adaptive frameworks) that made use of indicators considered across a wide range of disciplines and knowledge regimes. In our study, all indicators are equally weighted for these draft frameworks, following the logic of Cutter et al (2009), in that we do not have enough information to weigh them otherwise [208]. We make use of a human-environment place-based approach following Cutter et al (2009:31) in that, when it comes to developing a health vulnerability index specific to EWEs, we acknowledge that social vulnerability is independent of hazard type (ibid:23)[208]; however, health vulnerability is not. As such, our vulnerability assessment approaches take into account a general social vulnerability but are more specific when it comes to health in relation to hazard type (i.e., extreme weather event). Therefore, our approach used multiple indicators to engage with a range of impacts. These indicators were developed by drawing on research like Hahn et al [291] which was based on primary data gathered from household

surveys to develop several indicators to assess the impacts of climate change and variability in Mozambique, including a specific focus on health, food, water and natural disasters, as well as that of Yankson [240], Tyubee [232] (described in Chapter 3), and Dintwa et al's [214, 228] research. Once we determined a framework for each EWE, we developed a score sheet that aligned with the framework and began testing the ease of use of these frameworks among people who had experienced each EWE. Specific to Dintwa et al, but true in many of the studies outlined in Chapter 3, research highlights the reality that social vulnerability is often driven by household size, disability, level of education, age, people receiving social security, employment status, household status and levels of poverty. We therefore have included the gathering of key demographic vulnerability indicators as part of our HVI framework suggestions.

4.2.2 Methods and Process for Developing Draft Frameworks

The process we undertook to develop the frameworks was as follows:
1. Once all data was extracted from the studies in the scoping review, we cleaned the data;
2. All studies that were relevant to our topic, but did not provide data, were added to the literature review provided in Chapter 3;
3. The cleaned data was further extracted for specific health outcomes relevant to each EWE;
4. Tables were created for each EWE and related health outcomes;
5. A series of workshops where we met 2 – 3 times per week over the course of four weeks was undertaken to draft the framework, working backwards from health outcomes to develop a series of questions related to exploring those specific outcomes – i.e., developing a series of indicators on the pathways [292-294] related to specific health outcomes ;
6. The research team split into groups to workshop these questions to work through potential questions that could address the specific health outcomes raised in the evidence review;
7. Each research team then presented their draft frameworks to the larger team, where the frameworks were further edited and developed;
8. Simultaneously, demographics questions relevant to social vulnerability were developed and cross-checked against EWEs to reduce repetition;
9. Frameworks were refined, simplified and printed in large format for workshops;
10. Workshops/interviews with residents who had experienced various EWEs took place from 1 – 22 March 2022; and finally,
11. Feedback from workshops was reviewed, framework scores were consolidated, and frameworks were edited as needed.

The workshops to develop the frameworks took place 2 – 3 times per week over the course of five weeks (the final week of January through to the end of February). The following project members were involved in this phase of the project: Dr Amber Abrams, Dr Sithaihle Hlahla, Research Assistant Taherah Asmall, student researchers Lethabo Makgoba (MPH), Ridah Perrin (Honours/Masters social anthropology), Michaela Deglon, (MPH), Nomzamo Tshuma (medical school graduate), and to a lesser extent, because he became unavailable PhD candidate Tamuka Chekero (Social Anthropology).

4.2.2.1 Resident Workshop Details

We held workshops and individual interviews to test the frameworks and score sheets that were developed. We approached these focus groups and interviews with two key aims in mind; 1. Does the framework make sense? Is it easy to use?; 2. Are we missing any key health-related concerns that arose during residents' experiences of these EWEs? The first workshop, led by Abrams, in Muizenberg, focused on drought and helped the team refine the tools, including confirming the need to consider social vulnerability (especially livelihoods) in the context of residents' experiences around drought. The second workshop, in Sweet Home Farm, led by Abrams and attended by Asmall, Hlahla and Perrin, focused on floods, and helped us to add questions specific to fever experiences of residents who had experience with floods, while also confirming aspects already included in the draft framework (pictured below).

The third, a group discussion, held in Brooklyn, focused on heat and confirmed the need to discuss topics like roofing materials and ambient temperature inside homes and places of work.

The fourth workshop in Harare focused on drought and also indicated the social vulnerability associated with this EWE. The participants indicated that their access to food is affected, especially vegetables; there is water insecurity, as in some communities, water is sold to the residents; and there is a lack of government assistance during droughts, especially in urban areas. In Pietermaritzburg (KZN), the most important finding was the vulnerability of the elderly to extreme heat, which was exacerbated by the presence of various chronic conditions. Two important health concerns associated with extreme heat were noted: (1) the relationship between extreme heat and hypertension and (2) the aggravation of COVID-related fevers during extreme heat. In this sample, almost all participants had trouble with their eyesight, with two participants having only 50% vision and thus requiring assistance to fill out the score sheets. This only further highlighted the need to refine the score sheets, allowing them to be user-friendly for the elderly, e.g., increasing the font size. Workshop participants ranged in age from 20 – 60, and were invited through processes of first purposeful, and then snowball sampling. All volunteered and provided consent.

The workshop materials were in English. Although using a single language, like English, is a limitation of our method, related to time, it became clear that the language we used and the question forms were simple enough for local residents to follow. This was a key effort of our framework development workshops, where we purposefully simplified the language used, keeping in mind the varied levels of schooling and literacy among South African residents. When asked directly about how easy the questions in the framework were to understand and answer, all those who responded confirmed their understanding. Ideally, the materials should be translated and back-translated into local languages to ensure understanding, but due to budget and time constraints, that was not possible.

4.3 RESULTS: DRAFT FRAMEWORKS

Considering the literature on HVIs in the context of the variety of EWEs we engaged with, it is evident that some demographic considerations are important across the board (see Appendix C). At the same time, because of the complexity of issues related to each of the EWEs, it became a near impossible task to try to engage with all the EWEs in one framework. As such, we have developed three distinct frameworks, one each for flood, drought and heat. Below, the frameworks all work similarly in that they address the key health outcomes (from the evidence-based review) and concerns (from focus groups), and all group them according to the accepted general approach to vulnerability; i.e., considering exposure, sensitivity and adaptability. In the frameworks provided below, these different components of vulnerability are afforded different colours to make it easy to differentiate them. We provide here the overview slides of the framework, and offer more details of the framework in the appendices:

4.3.1 Flood Framework Overview

Description of the flood framework:

To develop this framework, we first gathered all the literature available on flooding (Block A) from our scoping review. We extracted various indicators from the research and divided them into three categories, i.e., exposure (blue circle), sensitivity (orange circle) and adaptation (blue circle). Within each of the three categories, we devised questions that we would use to guide our investigation into the vulnerabilities experienced by our participants. Listed below are the flood-specific questions for each category (the same process was followed for each weather exposure):

Exposure (Block B below, appendix C- Figure 9)
- Has your area/neighbourhood experienced flood recently? If yes,
  - How recent was the flood?
  - How many floods have occurred in the last year?
  - Did the flood water enter your home?
  - How long did the flood water remain in/around your home?
  - Did your household have to evacuate due to flooding?

Sensitivity (Block C below, appendix C- Figure 10 and 11)
- During the last flood, was anyone in your household injured? If yes,
  - Did they have to go to the clinic?
- During the last flood, did anyone in your household drown?
- During the last flood, was your livelihood disrupted?
- After the last flood, did you notice a change in your health or the health of anyone in your household because of the floods? If yes,
  - Did you or anyone else in your household experience diarrhoea?
  - Did you or anyone else in your household develop headaches or start vomiting?
  - Did you or anyone else in your household develop rashes?
  - Did you or anyone else in your household develop a cough?
  - Were they diagnosed with any of the following? Cholera, typhoid, E.coli, malaria, measles, schistosomiasis, any respiratory infection, any skin infections or other conditions?
- Did you or anyone in your household experience anxiety, trouble sleeping or distress due to the impacts of flooding? If yes,
  - Did they receive professional help/counselling?
- How often were you able to access clean drinking water? If yes,
  - What was your source of clean water?
- Did you have access to enough food? If yes,
  - Did you have access to the same kinds of flood you ate before the flood?

_____

o   Was your food supply/stores contaminated?

Adaptation (Block D below, appendix C- Figure 12)

- Did you receive assistance with clearing out flood water from your home or close environment after a flood event? If yes,
    o   How quickly was the clean-up completed?
- During flooding, were you able to access a clinic or hospital if needed?
- Did your area/community have an evacuation plan in place for severe flooding? If yes,
    o   Did you have access to another form of shelter?
- During/after the flood, if food was less available, did you have access to food aid/humanitarian aid?
- Did your household have access to water for hand washing?
- Do you have access to information about flooding in your area? If yes,
    o   What are your sources of information?
- Did you receive external support (e.g., community, government, private sector) during/after a flooding event?

_____

Figure 6. Flood Framework Overview

4.3.2 Heat Framework Overview (see appendix C for details)

Figure 7: Heat Framework Overview

4.3.3 Drought Framework Overview (see appendix C for details)

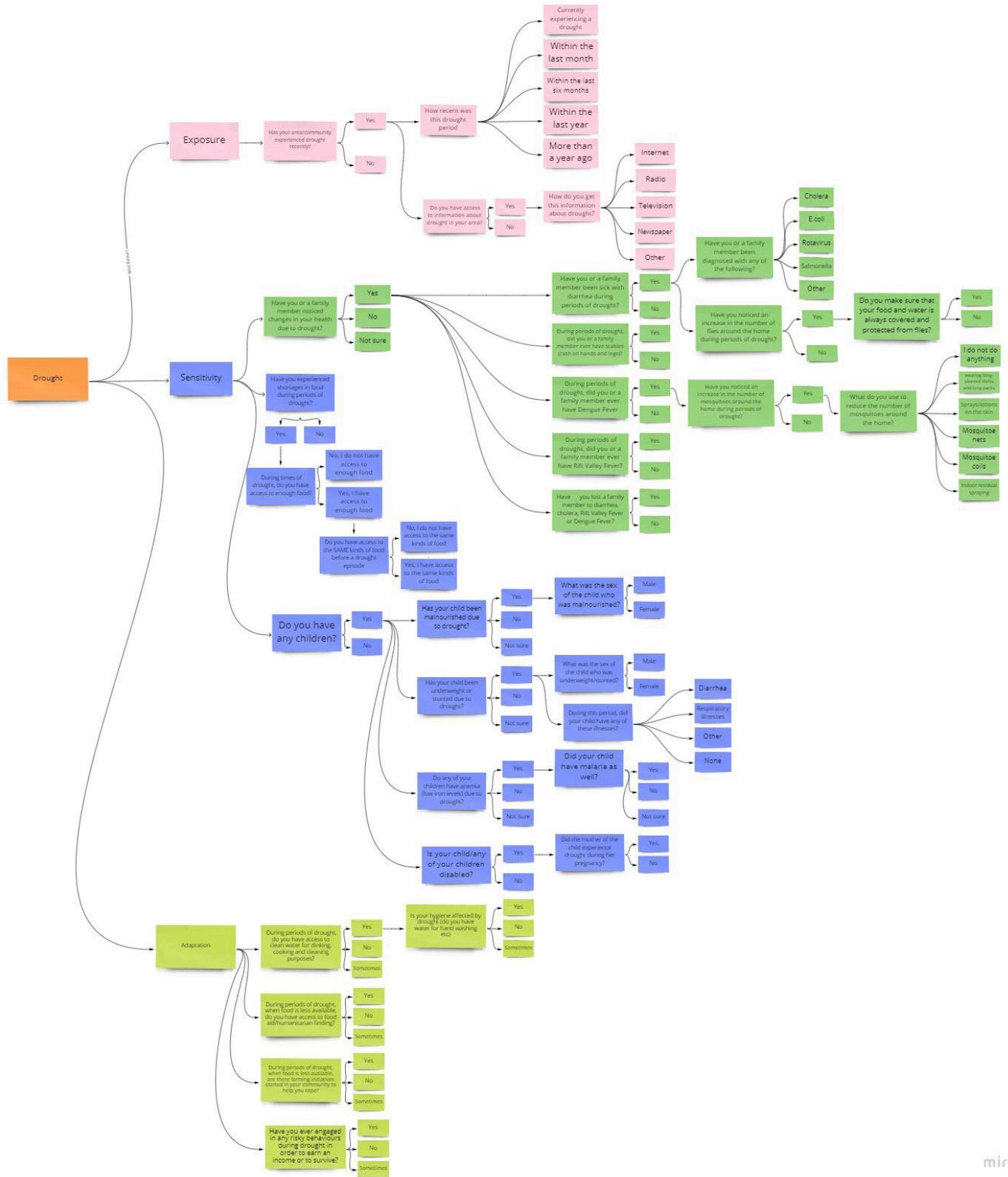**Figure 8: Drought Framework Overview**

4.3.4 Sample Flood Assessment Sheet

Flood Indicator Qs – Tabulation format

#	Exposure Question	Score
1	Has your area/neighbourhood experienced flood recently? Yes (1) No (0)	
	If No – Skip to other extreme weather event	
2	How recent was the last flood? Current (5) last month (4) past 6 months (3) past 12 months (2) more than a year (1)	
3	How many floods have occurred in your area in the last year? 0 (0) 1-2 (1) 3-4 (2) 5-6 (3) more than 6 (4)	
4	Did the flood water enter your home? Yes (1) No (0)	
	If No skip to 5	
4A	How long did the flood water remain in or around your home? <12hrs (0), 24-48hrs (1), 3-7 days (2), >7 days (3)	
5	Did your household have to be evacuated due to flooding? Yes (1) No (0)	
	Exposure score	/15

#	Sensitivity Question	Score
1	Did you notice a change in your health or the health of anyone in your household during the last flood? Yes (1) No (0)	
	If No skip to 3	
2	During flood, was anyone in your household injured? Yes (1) No (0)	
	If No skip to 2B	
2A	Did they have to go to the clinic? Yes (1) No (0)	
2B	During flooding did anyone in your household drown? Yes (1) No (0)	
3	During flood, was your livelihood disrupted? No, it was not disrupted at all (0) Yes, but I was able to continue with some work (1) Yes, totally disrupted (2)	
4A	Did you or anyone in your household experience diarrhea? Yes (1) No (0)	
	If No skip to 4B	
4A1	Did they/you have to go to the clinic? Yes (1) No (0)	
4B	Did you or anyone in your household develop headaches or start vomiting? Yes (1) No (0)	
	If No skip to 4C	
4B1	Did they/you have to go to the clinic? Yes (1) No (0)	
4C	Did you or anyone in your household develop a rash? Yes (1) No (0)	
	If no skip to 4D	
4C1	Did they/you have to go to the clinic? Yes (1) No (0)	
4D	Did you or anyone in your household develop a cough? Yes (1) No (0)	
	If No skip to 4E	
4D1	Did they/you have to go to the clinic? Yes (1) No (0)	
4E	Were they diagnosed with any of the following? Cholera (1) Typhoid/salmonella (1) E.Coli (1) Malaria (1) Measles (1) schistosomiasis (1) any respiratory infection (1) any skin infection (1) other condition (1)	
5	Did you or anyone in your household experience anxiety, trouble sleeping or distress due to the impacts of flooding? Yes (1) No (0)	
	If No skip to 6	
5A	Did they have to receive professional help/counselling? Yes (1) No (0)	
6	After the flood how often were you able to access clean drinking water? All the time (0) occasionally (1) hardly ever (2)	
6A	What was your source of clean drinking water? My usual water source was unaffected (0) Able to purchase clean water (1) treat own water (by bleach or boil) (2)	

	Clean water was provided by other parties e.g. NGO's (3)		
7	After the flood, did you have enough food? Yes (0) No (1)		
	If no, skip to 7A1		
7A	Do you have access to the same kinds of food that you had access to before the flood? Yes (0) No (1)		
7A1	During flood was your food supply/food stores contaminated? Yes (1) No (0)		
	Sensitivity score		/33

#	Adaptation Question _ ADAPTATION TOTAL SHOULD BE SUBTRACTED FROM THE SUMS OF THE OTHER TWO	Score
1	Did you receive assistance with clearing out flood water from your home or close environment? Yes, the flood was severe, and I received assistance (1) No, the flood was severe, and I did not received assistance (0) No, the flood was not severe, and I did not need assistance (0)	
1A	How quickly was the clean-up completed? A few hours (3) A few days (2) A few weeks (1) My home/environment still has flood water in it (0)	
2	During flood, were you able to access a clinic or hospital if needed? Yes, with no difficulty (4) Yes, with some difficulty (3) Yes, but only a few days later (2) No, the flood prevented me from reaching care, but other medical help was available (1) No, the flood prevented me from reaching care and there was no other help available (0)	
3	Does your area/community have an evacuation plan in place for severe flooding? Yes (1) No (0)	
3A	If you had to leave your home due to flooding, do you have access to another form of shelter? Yes (1) No (0)	
4	During and right after the flood, if food was less available, did you have access to food aid? Yes (2) Sometimes (1) No (0)	
5	Did your household have access to water to be able to practise WASH techniques such as washing hands with soap? Yes (2) No (0) Sometimes (1)	
6	Do you have access to information about flooding in your area? Yes (1) No (0)	
	If No – Skip to 7	
6A	If Yes, which one applies to you? I have immediate access to information about flooding (2) I have access to information when it is made available by other sources (1) I have access to information only through other people (0)	
6A1	How do you get this information about flooding? Internet (1) Radio (1) Television (1) Newspaper (1) Other (1)	
6A2	If Other, please explain _____	
7	Did you receive any other external support (e.g, community, government, private sector) during/after a flooding event? Yes (2) No (0) Sometimes (1)	
	Adaptation score	/24

4.3.5 Sample Heat Assessment Sheet

Heat Indicator Qs – Tabulation format

#	Exposure Question	Score
1	Has your area/neighbourhood experienced extreme heat/heatwaves recently? Yes (1) No (0)	
	IF NO – Skip to Q2	
2	How recent was the period of extreme heat/heatwaves? Current (5) last month (4) past 6 months (3) past 12 months (2) more than a year (1)	
3	Can you recall the maximum temperature? 30-34C (1), 35-40C (2), greater then 40C (3)	
4	Do you have access to information about extreme heat/heatwaves in your area? Yes (0) No (1)	

	If No – Skip to sensitivity questions	
5	How do you get this information about extreme heat/heatwaves? Internet (1) Radio (2) Television (3) Newspaper (4) Other (4)	
	If Other, please explain _____	
	Exposure score	

#	Sensitivity Question	Score
1	Have you or a family member noticed changes to your health due to extreme heat/heatwaves? Yes (1) No (0)	
	If No, skip to 1B	
1A	Have you or a family member experienced any of the following extreme heat related symptoms? Sweating/nausea/headache/reduced concentration (1) Weakness/dizziness/fainting/ confusion/ agitation (2) Fast shallow breathing/ feeling cold/ pale complexion (3) Irregular heartbeat/ rapid pulse (4) Seizures/ Cardiac arrest (5)	
	If No skip to 1B	
1A1	Are you female? Yes (1) No (0)	
1A2	Are you over the age of 60? Yes (1) No (0)	
1B	Do you have any pre-existing chronic illnesses? Yes (1) No (0)	
	If No skip to 1C	
1B1	Do you have any of these chronic illnesses? Heart disease (1), Diabetes Mellitus (1), Asthma (1), Any type of cancer (1), Genitourinary illnesses (1), Digestive illnesses (1), Psychiatric illnesses (1)?	
1C	Have you or any family member been hospitalized due to extreme heat exposure? Yes (1) No (0)	
	If No skip to 1D	
1C1	What was the reason for being hospitalized?	
1D	During periods of extreme heat did you or a family member ever have malaria? Yes (1) No (0)	
	If No skip to 1E	
1D1	Have you noticed an increase in the number of mosquitoes around the home during periods of extreme heat? Yes (1) No (0)	
1D2	What do you use to reduce the number of mosquitoes around the home? Nothing (5) wearing long-sleeved shirts and long pants (4) Sprays/lotions on the skin (3) Mosquito Nets (2) Mosquito Coils (1) Indoor residual spraying (0)	
1E	Have you lost a family member to extreme heat? Yes (1) No (0)	
	If No skip to 2	
1E1	What was the cause of death?	
2	Have you experienced shortages of food during periods of extreme heat/heatwaves? Yes (1) No (0)	
	If No, skip to 3	
2A	During extreme heat/heatwaves, do/did you have access to enough food? Yes (0) No (1)	
	If no, skip to 3	
2A1	Do you have access to the same kinds of food that you had access to before the period of extreme heat/heatwaves? Yes (0) No (1)	
3	Have you experienced shortages with water during periods of extreme heat? Yes (1) No (0)	
	If no skip to 4	
3A	During periods of extreme heat do you have access to enough water for hand washing, cooking etc?	
4	Do you have children living with you? Yes (1) No (0)	
	If No, skip to 5	
4A	Was your child born underweight due to the mother experiencing extreme heat during pregnancy? Yes (1) No (0)	
4B	Do you have any children under the age of 5 years? Yes (1) No (0)	
	If No skip to 5	
4B1	Has your doctor/local clinic/nurse said that your child is: healthy (0), underweight (1) or stunted (2)	
4C	During periods of extreme heat has your child suffered from diarrhea? Yes (1) No (0)	
5	Is your home made of materials that trap heat? Yes (1) No (0)	

#		Score
	If No skip to 5B	
5A	Does your home have the following: Tin/corrugated roof (1), Tin/corrugated sheet wall (1), Asbestos roof (1)	
5B	How many rooms does your home have?	
5C	How many windows are in each room?	
6	During heatwaves/ extreme heat, do you notice an increase in air pollution? Yes (1) No (0)	
	If No skip to Adaptation	
6A	What do you think causes this increase in air pollution?	

#	Adaptation Question _ ADAPTATION TOTAL SHOULD BE SUBTRACTED FROM THE SUMS OF THE OTHER TWO	Score
1	During periods of extreme heat/heatwaves do you have proper access to health care? Yes (0) No (1)	
	If No skip to 2	
1A	Are the health care facilities often overcrowded? Yes (0) No (1)	
2	During periods of extreme heat/heatwaves do you still have access to electricity? Yes (1) No (0)	
3	During periods of extreme heat/heatwaves do you have adequate access to water? Yes (1) No (0)	
4	Do you have access to appliances to keep you cool during periods of extreme heat? Yes (1) No (0)	
4A	What cooling appliances do you have? Fans (1), air conditioners (1)	
	Adaptation score	

4.3.6   Sample Drought Assessment Sheet

Drought Indicator Qs – Tabulation format

#	Exposure Question	Score
1	Has your area/neighbourhood experienced extreme heat/heatwaves recently? Yes (1) No (0)	
	IF NO – Skip to Q2	
2	How recent was the period of extreme heat/heatwaves? Current (5) last month (4) past 6 months (3) past 12 months (2) more than a year (1)	
3	Can you recall the maximum temperature? 30-34C (1), 35-40C (2), greater then 40C (3)	
4	Do you have access to information about extreme heat/heatwaves in your area? Yes (0) No (1)	
	If No – Skip to sensitivity questions	
5	How do you get this information about extreme heat/heatwaves? Internet (1) Radio (2) Television (3) Newspaper (4) Other (4)	
	If Other, please explain _____	
	Exposure score	

#	Sensitivity Question	Score
1	Have you or a family member noticed changes to your health due to extreme heat/heatwaves? Yes (1) No (0)	
	If No, skip to 1B	
1A	Have you or a family member experienced any of the following extreme heat related symptoms? Sweating/nausea/headache/reduced concentration (1) Weakness/dizziness/fainting/ confusion/ agitation (2) Fast shallow breathing/ feeling cold/ pale complexion (3) Irregular heartbeat/ rapid pulse (4) Seizures/ Cardiac arrest (5)	
	If No skip to 1B	
1A1	Are you female? Yes (1) No (0)	
1A2	Are you over the age of 60? Yes (1) No (0)	
1B	Do you have any pre-existing chronic illnesses? Yes (1) No (0)	
	If No skip to 1C	
1B1	Do you have any of these chronic illnesses? Heart disease (1), Diabetes Mellitus (1), Asthma (1), Any type of cancer (1), Genitourinary illnesses (1), Digestive illnesses (1), Psychiatric illnesses (1)?	
1C	Have you or any family member been hospitalized due to extreme heat exposure? Yes (1) No (0)	
	If No skip to 1D	

1C1	What was the reason for being hospitalized?	
1D	During periods of extreme heat did you or a family member ever have malaria? Yes (1) No (0)	
	If No skip to 1E	
1D1	Have you noticed an increase in the number of mosquitoes around the home during periods of extreme heat? Yes (1) No (0)	
1D2	What do you use to reduce the number of mosquitoes around the home? Nothing (5) wearing long-sleeved shirts and long pants (4) Sprays/lotions on the skin (3) Mosquito Nets (2) Mosquito Coils (1) Indoor residual spraying (0)	
1E	Have you lost a family member to extreme heat? Yes (1) No (0)	
	If No skip to 2	
1E1	What was the cause of death?	
2	Have you experienced shortages of food during periods of extreme heat/heatwaves? Yes (1) No (0)	
	If No, skip to 3	
2A	During extreme heat/heatwaves, do/did you have access to enough food? Yes (0) No (1)	
	If no, skip to 3	
2A1	Do you have access to the same kinds of food that you had access to before the period of extreme heat/heatwaves? Yes (0) No (1)	
3	Have you experienced shortages with water during periods of extreme heat? Yes (1) No (0)	
	If no skip to 4	
3A	During periods of extreme heat do you have access to enough water for hand washing, cooking etc?	
4	Do you have children living with you? Yes (1) No (0)	
	If No, skip to 5	
4A	Was your child born underweight due to the mother experiencing extreme heat during pregnancy? Yes (1) No (0)	
4B	Do you have any children under the age of 5 years? Yes (1) No (0)	
	If No skip to 5	
4B1	Has your doctor/local clinic/nurse said that your child is: healthy (0), underweight (1) or stunted (2)	
4C	During periods of extreme heat has your child suffered from diarrhea? Yes (1) No (0)	
5	Is your home made of materials that trap heat? Yes (1) No (0)	
	If No skip to 5B	
5A	Does your home have the following: Tin/corrugated roof (1), Tin/corrugated sheet wall (1), Asbestos roof (1)	
5B	How many rooms does your home have?	
5C	How many windows are in each room?	
6	During heatwaves/ extreme heat, do you notice an increase in air pollution? Yes (1) No (0)	
	If No skip to Adaptation	
6A	What do you think causes this increase in air pollution?	

#	Adaptation Question _ ADAPTATION TOTAL SHOULD BE SUBTRACTED FROM THE SUMS OF THE OTHER TWO	Score
1	During periods of extreme heat/heatwaves do you have proper access to health care? Yes (0) No (1)	
	If No skip to 2	
1A	Are the health care facilities often overcrowded? Yes (0) No (1)	
2	During periods of extreme heat/heatwaves do you still have access to electricity? Yes (1) No (0)	
3	During periods of extreme heat/heatwaves do you have adequate access to water? Yes (1) No (0)	
4	Do you have access to appliances to keep you cool during periods of extreme heat? Yes (1) No (0)	
4A	What cooling appliances do you have? Fans (1), air conditioners (1)	
	Adaptation score	

4.3.7 Demographics Sample Sheet

Concept	Proxy variable
General	**1.Name (Optional) or initials**
Age	**2. What is your age? _____**

Sex	**3. What is your sex?**
	    a) Male
	    b) Female

Marital status	**4. What is your marital status?**
	    a. Single
	    b. Married
	    c. Divorced/separated
	    d. Widowed
	    e. Polygamous marriage (married to more than one person)
	    f. Living with partner

Household head	**5. Are you the head of the household?**
	    a. Yes
	    b. No

Household size	**6.1 How many adult Male(s) are in the house? _____** **6.2 How many adult Female(s) are in the house? _____**

Children	**7.1 How many children below the age of 16 are in the household? _____**
	7.2 Please indicate the age and sex of each child in the household:
	Child 1: Age_____ Sex: (Male or Female) _____
	Child 2: Age_____ Sex: (Male or Female) _____
	Child 3: Age_____ Sex: (Male or Female) _____
	Child 4: Age_____ Sex: (Male or Female) _____
	Child 5: Age_____ Sex: (Male or Female) _____
	Child 6: Age_____ Sex: (Male or Female) _____
	Child 7: Age_____ Sex: (Male or Female) _____
	Child 8: Age_____ Sex: (Male or Female) _____
	Child 9: Age_____ Sex: (Male or Female) _____
	Child 10: Age_____ Sex: (Male or Female) _____
	
	7.3 Do any of the children take vitamin A supplements?
	    a. Yes
	    b. No
	    c. Sometimes
	7.4 If yes, how old are the children taking supplements? _____
	
	7.5 Is anyone in the household pregnant?
	
	    a. Yes
	    b. No

Elderly	**8. How many people above the age of 65 live in the household?** **_____**

Disability	**9.1 Does anyone in the household have a disability?**
	    a. Yes
	    b. No
	9.2 How many people in the household have a disability?
	_____

Education	**10. What is your highest level of education?**
	    a. No formal education
	    b. Primary (Grade 1-7), but not completed
	    c. Primary (Grade 1-7) completed
	    d. Secondary (Grade 8-12), but not completed
	    e. Secondary (Grade 8-12), completed
	    f. Tertiary (Post-Grade 12)/diploma/degree

Income	**11.1 What are your source(s) of income (you may select more than one option)**
	    a. Full-time employment
	    b. Part-time employment
	    c. Social government grants
	    d. Pension
	    e. Family or neighbor's support

	f. Other, (Please specify) _____

Household Employme nt	**12.1. How many people in your household are employed in these categories? (Refers to those 15 years old and above)**
	    a. Full time_____
	    b. Part-time_____
	    c. Contract_____
	    d. Unemployed_____
	    e. Pensioners_____
	    f. Self-employed_____
	
	12.2. What is the household's monthly income?
	
	    a. 0 - 5k per month
	
	    b. 6 - 15 k per month
	    c. 16 - 25 k per month
	    d. 26 - 35 k per month
	    e. >35k per month
	
	12.3. How many people are unemployed and depend on the household income (please count children as well)? _____

Social grants	**13.1 How many people are reliant on social grants? _____** **13.2 How many people are reliant on pension?** **_____**

Pre-existing illnesses	**1. Does anyone in the household have a chronic health condition?**
	    a. Yes
	    b. No
	1.2 If yes, how many have a chronic health condition?
	_____
	1.3. If yes, are they receiving treatment?
	1.3. If yes, how often do they go to the clinic?
	    a. Once a week
	    b. Once a month
	    c. Once every two months
	    d. Once every three months
	    e. Once every four months
	    f. Once every five months
	    g. Once every six months
	    h. Once a year

Water access	**2.1 What is this household's main source of water?**
	
	    a. Piped (tap) water in dwelling
	    b. Piped (tap) water on site or in yard
	    c. Public tap
	    d. Water-Carrier/tanker
	    e. Borehole on site
	    f. Borehole off site/communal
	    g. Rain-water tank on site
	    h. Flowing water/stream
	    i. Dam/pool/stagnant water
	    j. Buying from vendors
	    k. Well
	    l. Spring
	    m. Neighbour
	    n. Other (Please specify) _____
	
	2.2 How far is the water source from the dwelling?
	
	    a. Less than 100 m
	    b. 100 m - less than 200 m
	    c. 200 m - less than 500 m
	    d. 500 m - less than 1 km
	    e. 1 km or more
	    f. water on site (in the home)

	g. Don't know
Sanitation	**3.1. What type of toilet facility is available for this household?** a. Flush toilet b. Chemical toilet c. Pit latrine with ventilation pipe (VIP) d. Pit latrine without ventilation pipe e. Bucket toilet/Portable toilet f. Other (Please specify) e.g, open area_____ **3.2. Is the toilet facility shared with other households?** a) Yes b) No
Energy source	**4. What is your main source of energy?** a. Electricity from mains b. Electricity from generator c. Solar energy d. Wood e. Coal f. Paraffin g. Gas h. Animal dung i. Other**: _____**
Type of residence	**5.Which best describes your community?** a. Urban b. Peri-urban c. Rural
Housing structure	**6.1. Type of house:** a. Permanent (stone brick) b. Semi-permanent (e.g. mud wall, iron sheet) c. Thatch roofing with either stone or mud wall d. Polythene/wooden shack **6.2. Roof Type:** a. Tile or roofing b. Tin/corrugated sheets c. Asbestos d. Thatch e. Zinc f. Other, please specify_____
Accessible care	**7.1 How far is the clinic/hospital from your home?** a. The clinic/hospital is within walking distance for me (less than 5km) b. I can travel to the clinic/hospital with my own transport c. I can travel to the clinic/hospital using public transport d. The clinic/hospital is very far from my home and I have difficulty getting there **7.2 Are the roads in your area/community in good condition so that emergency services are able to get to you in case of an emergency?** a. Yes b. No
Food	**8.1 In the past four weeks, did you worry that your household would not have enough food?** a. Yes b. No **8.2 In the past four weeks, did any household member go all day and night without eating anything because there was not enough food?** a. Yes b. No **8.3 Do you grow your own crops for the household?** a. Yes b. No **8.4 If yes, what are the main reasons for growing farm produce for the household? (Please circle the correct option)** a. As a main source of food for the household b. As the main source of income/earning a living

	c. As an extra source of income
	   d. As an extra source of food for the household
	   e. As a leisure activity or hobby e.g. gardening
	   f. Other (please specify):_____
	8.5 Do you keep livestock for the household?
	   a. Yes
	   b. No
	8.6 If yes, what are the main reasons for keeping the livestock for the household? (Please select the correct option)
	   a. As a main source of food for the household
	   b. As the main source of income/earning a living
	   c. As an extra source of income
	   d. As an extra source of food for the household
	   e. Other (please specify): _____

Waste disposal and and drainage	**9.1 How do you dispose of solid waste/dirt/garbage?**
	   a. Throw anywhere outside the house
	   b. Dump very far outside the house
	   c. It is regularly collected by a garbage truck
	   d. It is infrequently collected by a garbage truck
	   e. I pay someone to go dump garbage
	   f. a pit dug outside the house
	   g. Burn the garbage
	9.2 What is the state of drainage around the house?
	   a. Non-existent (water comes in or flows closely past the house)
	   b. There is planned water drainage systems that work
	   c. There is planned water drainage systems but filled with garbage
	   d. I have dug a tunnel to divert water around the house

Coping with weather shocks	**10.1 Which statement best describes you?**
	
	   a. My livelihood is impacted entirely by extreme weather events (flooding, drought, extreme heat, wildfires)
	   b. My livelihood is challenged or made difficult by extreme weather events (flooding, drought, extreme heat, wildfires) but I am still able to make a living
	   c. My livelihood is not impacted by extreme weather events (flooding, drought, extreme heat, wildfires)
	
	10.2 How does the household cope with major income shocks (e.g drought, death of a breadwinner, job los etc.). Please circle Yes or No
	   a. Sell livestock (Yes/No)
	   b. Take on additional work (Yes/No)
	   c. Sell other assets (Yes/No)
	   d. Reduce spending (Yes/No)
	   e. Use own cash savings (Yes/No)
	   f. Reduce food consumption (Yes/No)
	   g. Borrow money from relatives (Yes/No)
	   h. Reduce or stop debt repayments (Yes/No)
	   i. Borrow money from stokvel (Yes/No)
	   j. Other, (please specify) _____

Community Cohesion Indicators	**11. Which statement best describes the community you live in? (Please select one)**
	   a. There is no community interaction or support. I am excluded from making decisions regarding my own community. There is no trust between members in the community.
	   b. There is very little community interaction or support. I am sometimes excluded from making decisions regarding my own community. There is not a lot of trust between members in the community.
	   c. There is good community interaction or support. I am always included from making decisions regarding my own community. There is a lot of trust between members in the community.

Conflict or violence	**During periods of extreme weather events (flooding, drought, extreme heat, wildfires), have you noticed changes in the level of violence in your area/community?**
	   a. Yes, there is an increase conflict over access to resources
	   b. Yes, there is an increase in interpersonal conflict (at home or among neighbors)
	   c. No there are no changes in the level of violence

4.4 SUMMARY AND FURTHER RESEARCH

In summary, we offer here building blocks towards a Health Vulnerability Index that is specific to extreme weather events. These building blocks should be understood as a useful set of questions linked to evidence-based health

outcomes as indicators related to extreme weather events. At the same time, we are aware that ample additional research is needed to ensure that these frameworks provide meaningful information for end-users.

Areas where more research is needed include further testing of the frameworks and scoring scales, as calibration across socio-demographics and geographical locations with more data would be necessary. In addition, while we tested the frameworks in settings where EWEs had been experienced, we have not tested these frameworks in areas currently experiencing EWEs or in the immediate aftermath of such devastation; we did not have access, nor did we think asking about experiences that were devastating and still being recovered from would be useful or fair. We suggest that future tests of these materials be done with translations available, and if possible, facilitated by those with language skills in multiple local languages.

In addition, due to the overwhelming amount of data related to EWEs and human health that we attempted to synthesize, we were faced with developing separate frameworks for the EWEs where data was available. As such, our framework explores EWEs in isolation, but we acknowledge that there is a need to understand the overlapping concerns and pressures faced by individuals when EWEs happen in concert or quick succession. Further research to amalgamate these EWE-specific indicators and to allocate scoring to the demographic questions, so that a single framework can be available for end-users experiencing multiple EWEs would be relevant and timely.

There are ample spaces in which this work can be used in collaboration with other ongoing, and similar efforts; this bottom-up approach allows local residents to assess their own situation, and so, when used in conjunction with other similar efforts in development through the DoH that are more top-down stakeholder approaches (municipal area managers assessing neighbourhoods, for example) a more complete picture of the planning needs, relative experiences, and actual outcomes will be available. Other research in development, including early warning systems research via weather scientists, can be considered in line with the contexts that create specific vulnerabilities to provide targeted information to people living in the most vulnerable settings (coastal, low-lying, wind-prone, etc). Emergency materials and support for rebuilding must take into consideration climatic contexts (i.e., zinc roofing in regions where extreme temperatures are increasing will not provide safe shelter). In addition, consideration of water-sensitive design, nature-based interventions, and alternative forms of engaging with building resilient cities (co-design with citizens) are avenues of discovery/planning/leadership and policy that this research indicates are important to creating adaptability among neighbourhoods in the face of mounting EWEs.

CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

5.1 CONCLUSIONS

While it is evident that there are a number of clear indicators for health vulnerability in relation to extreme weather events that are consistent across the vast diversity of spaces in Cape Town or southern Africa, the frameworks proposed in this research require more rigorous engagement and discussions. Approaches that combine multiple means of assessing vulnerability, including (but not limited to) GIS and risk mapping, alongside direct exploration of individual experiences, will provide for a more robust (and closer to reality) set of assessments. These assessments take time, and in many settings, time is money, so expectations related to these types of engagement should include space to address the length of time and efforts associated with these tools. In other words, striking a balance between unpacking the variety of experiences people have, while not taking up too much of their time, is key, and at the same time, difficult to achieve.

An HVI that is useful to local residents to assess their vulnerability must be simple and not too time-consuming. However, the more simplified these indicators become, the less robust and specific they are, making them less useful to urban planners or city officials. In this way, a final layout for such a tool would depend on the end-users and their aim. What we offer is a series of pathways to health outcomes drawn from the evidence base, which have been confirmed and supplemented by local residents and their experiences. With this in mind, we offer an intricate mapping of health outcomes and potential indicators, and suggest that these be used in a variety of ways, dependent on end users and aims. To this end, the following recommendations for using these materials are provided below.

5.2 RECOMMENDATIONS

- Evidence-based indicators are only as good as the research that has been done – there are many gaps in the evidence base, and thus we suggest more research specific to the southern African context around people's health outcomes when faced with EWEs is an area of need.
- The indicators (questions related to health pathways towards outcomes) we have provided are useful as building blocks to understand pathways to specific health outcomes, but we recommend that these only be used in consultation with local residents to understand their local validity and usefulness
- The scoring system we offer should be further refined with more dedicated research to understand where score ranges should be cut off in relation to categorizations of types of vulnerability
- Making use of these indicators requires that users understand that these self-reported indicators are relative, and subjective – they are, as their name suggests, indicators, and not necessarily clear pictures of lived realities
- This research has highlighted the difficulty in decoupling socio-economics and health vulnerabilities, particularly those associated with household locations and neighbourhoods; as such, major planning shifts are needed, as are simple interventions like attending to changing housing materials where possible; in the context of extreme temperatures, for example, alternatives to zinc roofing should be sought.
- These indicators and frameworks should be used in concert with already existent (and validated) CRVAs, including those specific to southern Africa, like the Greenbook; efforts undertaken using top-down approaches by national and local departments of health; and weather science projections and early warning systems.
- Early warning systems for storms are important processes to make residents most affected by EWEs aware of; these systems should be widely accessible to the public so that acute health experiences related to EWEs can be avoided.
- Planners, policy-makers and other municipal officials should heed the data outcomes and experiences relayed in this report, and consider the value of water-sensitive design and urban resilience planning,

including attention to drainage and infrastructure accessibility, alongside these specific health outcomes to address hazards associated with EWEs.

- Follow-up research is needed to further test the indicators for a variety of settings, to develop the materials already created into more user-friendly tools, and to ensure that the data in this report is published in spaces where its relevance is useful (i.e., disaster planning, healthcare service delivery, local resident working groups to prepare for disasters).

CHAPTER 6:   APPENDICES

6.1   APPENDIX A: SEARCH STRATEGIES (EXCLUDING DROUGHT)

The development of a feasible search strategy required a directed question(s) in order to retrieve articles that were relevant to the project objectives. There are three aspects that needed to be defined i.e. exposure, outcome and place. The search strategies below are for flood/storms, extreme heat and wildfires, the search strategy for drought is published in Asmall et al [22].

Exposures
hot temperature OR global warming OR greenhouse effect OR extreme heat OR heat vulnerability OR heat wave OR heat waves OR heatwave OR heatwaves OR greenhouse gas OR greenhouse gasses OR GHG OR temperature extreme OR heat stress OR heat exhaustion OR climate change OR "Hot Temperature"[Mesh] OR "Climate Change"[Mesh] OR "Greenhouse Effect"[Mesh] OR "Extreme Heat"[Mesh] OR "Heat Stress Disorders"[Mesh]

Wildfires [MeSH] OR Smoke Inhalation Injury [MeSH] OR Wild fire OR wild fires OR wildfire OR wildfires OR smoke inhalation

Floods [MeSH] OR flooding OR inundate OR storm OR tropical storm OR cyclonic storms [MeSH] OR typhoon

Outcomes
Health [MeSH] OR Health Status [MeSH] OR Risk Factors [MeSH] OR health OR risk factors OR risk exposure OR risks

Region
Africa OR African OR Algeria OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR "Canary Islands" OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR Djibouti OR Egypt OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Ivory Coast" OR "Cote d'Ivoire" OR Jamahiriya OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Mayotte OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Principe OR Reunion OR Rwanda OR "Sao Tome" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR "St Helena" OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR "Western Sahara" OR Zaire OR Zambia OR Zimbabwe

Table 6.1 <u>Article totals:</u>

	Extreme heat	Flooding and storms	Wildfires	Total
Pubmed	2498	476	50	3024
Web of Science	3927	1119	40	5086
Africa Wide	2173	537	64	2774
Scopus	3732	941	57	4730
Total	12330	3073	211	15614

Extreme heat:

Search: **((Hot Temperature [MeSH] OR Global Warming [MeSH] OR Greenhouse Effect [MeSH] OR extreme heat OR heat vulnerability OR heat wave OR heatwaves OR hot temperature OR temperature extreme OR heat stress OR heat exhaustion) AND (Health [MeSH] OR Health Status [MeSH] OR Risk Factors [MeSH] OR health OR risk factors OR risk exposure OR risks)) AND (Africa OR African OR Algeria OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR "Canary Islands" OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR Djibouti OR Egypt OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Ivory Coast" OR "Cote d'Ivoire" OR Jamahiriya OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Mayotte OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Principe OR Reunion OR Rwanda OR "Sao Tome" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR "St Helena" OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR "Western Sahara" OR Zaire OR Zambia OR Zimbabwe)** Filters: **from 2007 - 2021**

Wildfires and smoke inhalation:

Search: **((Wildfires [MeSH] OR Smoke Inhalation Injury [MeSH] OR Wild fire OR wild fires OR wildfire OR wildfires OR smoke inhalation) AND (Health [MeSH] OR Health Status [MeSH] OR Risk Factors [MeSH] OR health OR risk factors OR risk exposure OR risks)) AND (Africa OR African OR Algeria OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR "Canary Islands" OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR Djibouti OR Egypt OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Ivory Coast" OR "Cote d'Ivoire" OR Jamahiriya OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Mayotte OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Principe OR Reunion OR Rwanda OR "Sao Tome" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR "St Helena" OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR "Western Sahara" OR Zaire OR Zambia OR Zimbabwe)** Filters: **from 2015 – 2021**

Flooding and storms:

Search: **((Floods [MeSH] OR flooding OR inundate OR storm OR tropical storm OR cyclonic storms [MeSH] OR typhoon) AND (Health [MeSH] OR Health Status [MeSH] OR Risk Factors [MeSH] OR health OR risk factors OR risk exposure OR risks)) AND (Africa OR African OR Algeria OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR "Canary Islands" OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR Djibouti OR Egypt OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Ivory Coast" OR "Cote d'Ivoire" OR Jamahiriya OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Mayotte OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Principe OR Reunion OR Rwanda OR "Sao Tome" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR "St Helena" OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR "Western Sahara" OR Zaire OR Zambia OR Zimbabwe)** Filters: **from 2016 - 2021**

6.2   APPENDIX B: SCOPING REVIEW RESULTS TABLES

Details of included studies are provided in the tables below – separated by type of EWE.

6.2.1 Flood Table

Table 6.2 Flood

Author name(s) and year of publication	Study population and design	Methods	Findings
		FLOODS	
Abiona 2017	Cross sectional study examining the impact of exposure to early life rainfall shock (drought and flood) on children's anthropometric growth status and other welfare outcomes (schooling and satisfaction levels).	Household level data was taken from the Malawi Living Standard Measurement Study, Integrated Survey on Agriculture (LSMS-ISA) and had three intervals: (1) 2004-2005- 11 280 households and 49 066 individuals; (2) 2010-2011- 3246 households and 15 582 individuals; and (3) 2013- 4000 households and 20 076 individuals. Monthly gridded precipitation data from 1900-2014, was taken from the Centre for Climatic Research. Rainfall estimates were taken from weather station data. Using Global Positioning Systems (GPS), communities were matched with the closest four weather stations to obtain historical rainfall data. Rainfall shock is constructed around the period of birth and locality of birth so assess the impact of the weather extremes on health outcomes. Child outcomes used were weight-for-age (WAZ) and height-for-age (HAZ) was used as a proxy for nutritional status. Z-scores below two standard deviations for WAZ and HAZ was considered underweight and stunted for WAZ and HAZ respectively. To assess the pooled effect of early life shock, a comparison of the mean difference in child growth, for children born around the same time, across communities, was done.	Climatic shock has substantial impact on health outcomes of children between 6-59 months in Malawi. Drought was found to have a more significant impact on poor childhood outcomes as opposed to flooding. Compared to international reference measurements, the age-normalized weight and height measurements were skewed to the left (standard deviation was 0.6 and 1.6 for weight and height respectively) suggesting Malawi children are underweight and stunted. In this study, 9% of children were underweight and 39% stunted. In-utero flood exposures, increased weight, and height by 0.194 and 0.416 standard deviation units for WAZ and HAZ respectively (significant at 1% level). Flood exposures during the first and second year of life was found to have an insignificant effect on weight outcomes. HAZ increased by 0.203 standard deviation units for flood events. Flood exposures on HAZ during the first and second year of life was found to have no impact. The stunting ratio by gender showed that boys were more stunted than girls i.e. 42% vs. 36% respectively. When the HAZ is aggregated according to age, The prevalence of stunting was the lowest in the first year of life accounting for only 18%. The prevalence of stunting in the second, third, fourth and fifth years of life are 38%, 49%, 43% and 39% respectively. The long-term effects of rainfall shock on delayed entry into school and welfare was found to be weak and insignificant. The effects of floods on adult self-reported well-being was less pronounced than the effects of drought.
Abu and Codjoe, 2018	Cross-sectional study in Accra, Ghana, investigating the experience and future	Simple sampling was used to select eight areas, classified as slums, in JT (n=202 households) and five in AB (n=199 households) located on the Odaw River. Participants were those directly affected by flooding that occurred on 26	In JT and AB 7.4% and 52.3% of participants, respectively, experienced the October 2011 flood event and reported cases of diarrhoea four weeks after. In total, 20% of respondents did not experience flooding but members of the household still experienced diarrhoea. The perceived risk of disease was 18% in AB and 5% in JT.

	perceived risk associated with floods and diarrheal disease. The study areas selected were James Town (JT) and Agbogbloshie (AB)	October 2011. Structured questionnaires collected information on demographics, location, month they were affected, experience with and risk perception of flooding and diarrhoea over the last year.	This discrepancy could be due to sanitation interventions in JT, less governmental assistance in AB and the increased likelihood of flooding in AB.
Adams and Nyantakyi-Frimpong, 2021	Qualitative study investigating the impacts of flooding as perceived by the community of Old Fadama, the existing vulnerabilities in the community and the physical and mental health outcomes associated with climate-induced flooding	There was no objective measure for flooding. However, photographs were used to depict flooding in the area. The study had four phases. In phase 1, participants were purposive sampled and recruited by two local residents from Old Fadama. In phase 2, a one-day training session was held. Participants were given photovoice training, taught how to operate the camera and ethical considerations around taking pictures. Participants were asked what the "general" impacts of flooding and to take pictures to demonstrate that. In phase 3, in-depth interviews were held with participants in English, Ga and Twi. The SHOWED approach was used. In phase 4, qualitative interviews were transcribed verbatim and a systematic, and iterative approach was used for data analysis. Data was grouped into sub-themes and master themes.	Participants experienced acute anxiety (n=47 photos) and chronic stress (n= 33 photos) due to flooding. People are afraid of drowning, had to stand throughout the night and try to clear out excess water. Old Fadama created a sense of self for the participants and, therefore, considering whether to leave their homes in search of safer accommodation caused internal conflict (n=28 photos). Prolonged stagnant water, contaminated with waste, increases the incidence of infections (n= 32 photos), injury (n= 30 photos), illness (n=41 photos) and death (n=10 photos). Illnesses reported included malaria, typhoid, cholera, and diarrhoea. There is also an increase in food-borne infections, which results in diarrhoea, vomiting and fevers. Death was also noted as a common impact of flooding through people being washed away or electrocution. Flooding caused a loss to tangible and intangible goods (n=33 photos) impacting the livelihoods. Recovering from the impacts of floods requires extensive time and labour (n= 28 photos) and many experience an inability to work (n=26 photos). There are concerns about flood-related conflicts which arise due to misunderstandings and building frustrations. Old Fadama was a refuse site which was waterlogged, and the environment is not conducive for living. Water seeps through even cement floors. Three participants reported that everyone is equally vulnerable to the effects of flooding. However, 17 participants reported that women and children are more vulnerable. Women are vulnerable due to the type of work they do, they have to take care of children who cannot go to school due to flooding and both groups present with sores on their feet due to prolonged time standing in stagnant water. Six participants report that class, age and sex cause differential vulnerabilities. Poor urban planning, marginalization and inequality has been highlighted as reasons why the community of Old Fadama is vulnerable to recurrent floods.
Adeagbo et al., 2016	Cross-sectional study to evaluate the effects of natural disasters on the livelihoods, households and well beings of individuals in Nigeria.	Six distinct geopolitical zones were purposively sampled. Questionnaires were administered to adults or household heads. A total of 1116 participants (712 rural and 404 urban residents) were selected using stratified random sampling.	The main health outcomes reported was disaster-related injuries and the occurrence of infectious diseases. Additionally, participants reported negative impacts on income, damage to dwellings, loss of household assets, school attendance disruption, damage to water source and electricity infrastructure and damage to roads and bridges which impacts mobility.

Adelekan and Fregene, 2014	Mixed method study to assess the vulnerability of a Nigerian artisanal mining communities to flood risk	The study was conducted in the rural area of Ogun where fishing is the pre-dominant source of livelihood. Five villages were randomly selected and grouped according to proximity to the coastal line. Surveys were conducted on 152 households and six focus group discussions and interviews with 11 key informants were held. Exposure risk and sensitivity were ranked on a scale of 1-5, which was then weighed according to the prevalence of each livelihood. Narratives were used to obtain information on the extent of flooding and knowledge regarding flooding (current and indigenous).	The study found the loss of life was related to disease occurrence, and drowning, and eye problems linked to smoking fish over wet wood during flooding. Other concerns raised were an absence of healthcare facilities and government neglect. Additionally, participants report cases of flood-related food insecurity due to inundation of food crop and loss of fish stock. Livelihoods are impacted by loss of assets which are necessary for fishing activities.
Ahmed et al., 2018	Mixed method study used to investigate the association between flooding and the occurrence of kidney disease in Nigeria's Hadejia-Nguru wetlands	Participants were purposively sampled from communities and health centres around the wetland areas. Using semi-structured questionnaires, data on flooding, river characteristics, livelihoods, community impacts, incidence of kidney and other diseases and cultural/traditional beliefs were obtained. Focus group discussions (FGDs) and in-depth interviews were held in target sites. Snowballing technique was used to select participants for interviews. A key informant was selected based on referral from community members or health centres. Spot-check observations involved recording observations made in the field. Water bodies were investigated for hydrological conditions. This information was consolidated with information around flooding events, flood damage and kidney disease records. Rapid analysis of water quality (nutrient and heavy metals) was done from the wetland area.	Communities reported widespread kidney disease and females appear to be more affected. Medical records showed that 2 out of 5 patients reporting to the medical centre have chronic kidney disease (CKD). Records from Federal Medical Centre (FMC) for the last six years show that 658 patients came in for treatment with 1736 dialysis sessions. Participants strongly believe that their water sources are the cause of kidney disease. Exposure to ground water contaminated with heavy metals from industrial run-offs used to improve agricultural productivity, dietary intake of aristolochic acid (from herbs), exposure to viruses, fungi, parasites, and water-related diseases are associated with kidney diseases..
Alexander et al., 2017	Ecological study to examine the relationship between surface water and annual flood dynamics on water borne diseases.	Meteorological data pertaining to max temp, rainfall, and river height was taken from 2007-2017 from the Department of Meteorological Services. Average estimates of temperature and rainfall in Chobe District was derived. Water samples were taken bimonthly from 2011-2017 from 14 sites along the Chobe River to determine E.coli concentrations. Diarrheal case reports from 10 healthcare facilities and passive surveillance systems. Diarrhoea is defined as the occurrence of at least 3 loose stools in a 24-hour period within the 4 days preceding the health facility visit. Diagnoses were categorized according	Severity of diarrhoea as diagnosed by nurse or physician and was characterised as diarrhoea with no dehydration, with some dehydration, with severe dehydration, or bloody diarrhoea. Seasonal diarrheal outbreaks occurred bimodally during high rains (wet season) and low rain (dry season) with worse outbreaks during drought periods. Wet season peaks affected children under 5 more while dry season peaks affected older children and adults more. Diarrhoea was mostly severe with more than half of all-age cases presenting with some or severe dehydration.

The E. Coli levels and total suspended solids (TSS) also exhibiting seasonal patterns. E.coli concentrations were low during the dry season and highest during the middle of the wet season. While TSS was highest during the dry season and declined during |

		to the International Classification of Diseases- 10th Revision.	the wet season. During this period, a one-meter drop in river height corresponded to an estimated 16.7% and 16.1% increase in reported diarrhoea with a 1- and 4-week lag, respectively. In this region, as floodwaters receded from the surrounding floodplains, TSS levels increased and were positively associated with diarrheal cases (0- and 3-week lag). Populations living in this region utilized improved water sources, suggesting that hydrological variability and rapid water quality shifts in surface waters may compromise water treatment processes.
Atufu and Holt, 2018	A qualitative study to evaluate flooding impacts on the populations of Lagos, Nigeria in five areas of Lekki, Victoria Island, Ikeja, Surulere and Ikorodu.	Lagos experiences equatorial climate with year-round rainfall. Flooding has become an annual event due to short duration high-intensity or long-duration low intensity rainfalls. Flood events occurred in 2010, 2011 and 2012. The 2010 Ikorodu floods caused significant damage and displacement of 1700 people. From the 16 Local Government Areas (LGAs), five were selected and identified as being vulnerable to flooding. The study sampling of the residents was stratified by the population area. A total of 600 questionnaires were distributed on an opportunistic basis. In Ikorodu and Surulere 150 questionnaires were distributed. In Lekki, Victoria Island and Ikeja 100 questionnaires were distributed to each area. The overall response rate was 47%.	From the participants, 80% experienced flooding while living in Lagos and 60% experienced flooding in their current residence. Ikeja, which has well maintained drainage systems, experienced a lower proportion of flooding compared to Lekki, 54% vs. 65%, respectively. Lekki had the greatest number of participants who experienced flooding in their existing residence. Despite high flood exposure only 20% considered flooding risk when relocating. No association was found between flood risk and property considerations [X2 (4, n=55) = 7.27, p>0.05]. Flooding generally occurs in the rainy seasons.. The study found that 11.3% of the residences or one of their family members were hospitalised due to flooding. It was reported that 5.6% lost their life due to flooding. Participants experienced damage to property (38.4%), disruption in travelling (34.2%) and displacement (31.3%).
Boyce et al., 2016	Quasi-experimental study to investigate the association between severe flooding and malaria incidence in an endemic region in western Uganda.	The study was conducted in Bugoye, Kases District, which experienced heavy rains and flooding in May 2013. Malaria diagnostic testing results from health centre laboratories and inpatient malaria-related hospitalization records before and after the flooding was used. The study population was sampled from 31 villages and included 7596 individuals. To assess the flood-related spatial and temporal epidemiology of malaria, geographical information system mapping was done for the village level of Bugoye and its surrounding environments. Data was entered into ArcGIS to make a reference map to calculate the mean elevation of each village which was divided into quartiles to define villages by the absence or presence of a river which could cause flooding.	From a total of 10 134 patient tests done, only 7596 results were eligible to use for the study, of which 89% were residents from villages containing a flood-affected river. In the post-flood period, the risk of an individual having a positive malaria test result for villages nearby rivers increased by approximately 30%. The impact of flooding was larger upstream compared to downstream with the adjusted incidence rate ratio (AIRR) of 1.91 vs 1.33. Following the flooding the number of individuals admitted with malaria increased by more than 50% (781 vs 504; P < .001). The AIRR remained high after adjusting for confounders such as river presence and village elevation (AIRR, 1.40; 95% CI: 1.16-1.69; P < .001). From all hospital admissions, the proportion admitted for malaria significantly increased (54.1% vs 45.4%; P < .001). The authors note trends between malaria incidence and flooding, river presence, location along the river, or the elevation of the village but this was not statistically significant.
Bryson et al., 2021	Qualitative study to assess maternal food security, nutrition and	The study used an adapted climate change conceptual framework and a community-based approach. A total of 36 women were included (24 Batwa and 22 Bakiga). The	Both indigenous and non-indigenous groups faced similar exposures. However, the Batwa women had more severe experiences during the dry season with them reporting "We just boil and drink water only." Some Bakiga women reported being

		research group consisted of indigenous community members and local health practitioners. Focus group discussions (FGDs) were conducted in four Batwa communities and four geographically matched Bakiga communities in the Kanungu District. Each group in the study had 5-6 women, of diverse age groups. A semi-structured interview guide was used and included information on antenatal diet, perceived and observed climate-associated impacts on nutritional and pregnancy outcomes. The term "climate change" was not used as it is an unfamiliar term to participants. Instead, the focus was on long-term patterns and changes during wet and dry seasons and the changes.	occasionally too ill to work for food during their pregnancy. Bakiga women said that they did have the capacity to cope with the weather variability. A Batwa Elder spoke to the loss of their traditional lands which provided them honey, yams, meats, and medicinal herbs. This allowed them to better care for mothers and babies to improve their immunity. The indigenous communities, except for one community reliant on tourism for livelihood, were disproportionately affected by food insecurity. This one community did not report that seasonality affected their food security and said that improved tourism improved food security. When women are unable to work, only some received social support from the men. Women reported that pregnancy decreased their ability to cope with climate-related adverse health effects. Participants had different opinions on which season was associated with better maternal wellbeing during pregnancy. Women reported that better healthcare access results in better health of young children. Babies born in the rainy seasons are in better health as mothers having better access to food in this season. Babies born more recently are small, weak, and having more sickness. One woman attributed this the mother not having enough food. During the rainy seasons, women are able to work for cash in order to have money to buy food. Women described that the amount of food intake during pregnancy was variable, with the greatest intake during the late stages of pregnancy. Therefore, food security in this stage is more crucial. Ideally, women voiced interest in timing of pregnancy around seasons with higher food security.
health in the context of climate change among rural Ugandan women			
Cools et al., 2020	Cross sectional study to analyse the effect of rainfall shocks on intimate partner violence (IPV) in sub-Saharan Africa	The total sample was 149 000 women from 17 African countries. Data was collected using the demographic and health survey (DHS) and included a GPS coordinate at the cluster level to geographically link to relevant local weather data. The surveys were given to women who live or ever have lived with an intimate partner and contains a series of questions related to IPV including the experience of violence within the last 12 months prior to the interview. In part 2, only nine countries were included for repeat analysis. The standard lapse between survey times was 5 years whereby clusters are not surveyed again but repeat observations were recorded. Parts 1 and 2 explored how rainfall shocks would impact relative wealth. Households were ranked along a continuum of relative wealth. In part 3, the data from a sub-sample of married women cohabitating with a partner, who were victims of violence from their most recent partners (n= 50 512) was used.	There is no association between drought and intimate partner violence. In the first analysis (n= 149 000), 26% of women reported IPV in the past year, while 32% reported experiencing IPV at some point in their lives. In this study, relative measures of drought and floods were constructed from 1979-2011 using grid-specific gamma distribution of rainfall. The regression analysis shows no significant association between IPV and drought (at the 2.5% and 10% level). However, floods appear to increase IPV during the last rainy season. However, when the polynomial analysis was done for the second analysis of nine countries, floods and drought (10% level) were found to be negatively associated with IPV. In the third part of the analysis, the total years at risk was 233 755. The recall of yearly hazard rates is higher for those married less than 10 years vs. those married for more than 10 years and the hazard rates decline with an increase in years of marriage. This suggests that women who are married for a longer time tend to underreport episodes of violence and with less precision. In this sample, there is a greater risk of women being victims of violence in the first two years of marriage for those married less than 10 years. There is a statistically significant decrease (0.6 percentage points) in the yearly risk of violence

			at the 2.5% level of drought. Drought lowers relative household wealth but does not increase intimate partner violence.
Di Baldassarre et al., 2010	Ecological study investigating climatic factors which influences the occurrence of flooding in Africa	Authors used data from a large, quality assured database provided by the International Association of Hydrological Sciences to obtain flood data from 1900-2000. Hydrological changes are represented spatially and temporally across averaged climatic conditions. Study areas were categorised according to different climatic regimes. Thirty catchment areas with ≥30 years of records were included and separated into three categories according to flood regime i.e., high, medium, and low flood rates. The data was further categorised into tropical, sub-humid, and semi-arid areas. Human fatalities from Africa, between 1950-2010, by the Centre for Research on the Epidemiology of Disasters was used. The number of fatalities per flood was not accounted for nor whether these fatalities were directly resultant from injury, drowning or disease etc. Flood vulnerability data appears to be a combination of total and urban population growth as provided by the United Nations.	The total and urban population both increased. The total population increased by a factor of 4 and the urban by one order magnitude, which is approximately the same increase seen in flood-related fatalities. The results showed that in places where the recent deadly floods have occurred, the population increased. On a local scale, there is an increase in human settlements in floodplains. In the capital city of Zambia, Lusaka, the fast growth in flood-prone areas has strongly increased flooding risks. The same can be seen in Alexandria (Egypt), Dakar (Senegal) and Ouagadougou (Burkina Faso) which were all greatly affected by the 2009 flooding.
Elsanousi et al., 2018	A retrospective observational study assessing the impact of the 2013 floods on malaria incidence in Almanagil Locality, Gezira State, Sudan.	Surveillance data and hospital records for malaria incidence was used. Data on confirmed malaria cases was obtained from Almanagil Locality's sentinel malaria notification sites (SMNSs). For the years 2011-2013, the data was taken from the weekly reports of 13 SMNSs (nine hospitals and four health facilities). This data is used to determine the malaria incidence rate (IR) and the slide positivity rate (SPR). The Almanagil Locality's nine hospitals gathered data on outpatient cases. Eight of the nine hospitals gathered data on inpatient malaria cases and the data was gathered from the Gezira State MOH's Statistics Department's monthly reports for the years 2011-2013. The data included the monthly totals of all outpatient and inpatient diagnoses, as well as confirmed malaria cases.	Malaria cases increased significantly in the 13 SMNS's, the IR increased from 6.09/100,000 person days in 2011 to 6.48 in 2012 to 8.24 in 2013. With the IR peaking in the <5-years age group, the IR for this age group jumped from 9.80/100,000 person days in 2011 and 10.00 in 2012 to 15.02 in 2013. In 2013, the proportion of hospital OPD patients was 19.7%, up from 12.85% in 2011 and 12.16 percent in 2012. The <5-year-old age groups were responsible for the overall increase in malaria cases in 2013, particularly the under-1-year-old age group, which more than doubled in 2013 (19.5%), up from 7.7% in 2011 and 8.1% in 2012.In 2013, the proportion of severe malaria cases (inpatients) increased to 22.5%, from 19.8% in 2011 and 18.4% in 2012. The rise in the proportion of severe malaria cases was mostly owing to a larger number of children <5 and children <1 year. In comparison to the same periods in 2011 where the SPR = 8.72% and 2012 where the SPR = 12.62%, a noticeable increase in the slide positivity rate was observed in the 12-week period of 2013 where the SPR =20.86%, with a more marked rise of the SPR in the <5 age group.
Emmelin et al., 2008	Retrospective study to characterize the period's (1998-1999) mortality	Butajira Rural Health Programme collects individual population-based data from the Butajira region by routine surveillance. The data included all deaths registered at the	In the study period (1997-2001), 3,512 fatalities occurred out of 222,891 person-years (p-y) of observation, resulting in an overall mortality rate of 15.8 per 1,000 p-y. However, 37.8% fatalities (1,327) occurred in 1999 and 22.8% deaths (801) in 1998,

	epidemiology by using individual, longitudinal population-based data from the Butajira demographic surveillance site and rainfall data from a nearby site.	household level and self-reported cause of death in a 5-year period between 1997-2001. Monthly rainfall estimates were taken from a local weather station in Butajira. The data from 1987-2003 was provided by the National Meteorological Authority. Additionally, crop statistics were taken from the District Agriculture Bureau of the Meskan and Mareko District Authority.	resulting in a mortality rate of 24.5 per 1,000 people per year from 1998 to 1999, compared to 10.2 per 1,000 people per year for the rest of the 5-year period. The death peaks in 1998 and 1999 were observed in all age categories but were most pronounced in children under the age of five, who had the highest rise in mortality rates. Children under the age of five accounted for 47.2 % of all deaths. Malaria or diarrhoea/malnutrition appear to have caused most of the increased mortality in 1998 and 1999. During 1998 to 1999, 364 rural people died from malaria and 614 from diarrhoea/malnutrition. Malaria deaths were more likely in those over the age of 5 years, while diarrhoea/malnutrition deaths were less likely between 5-50 years. Malaria deaths were more common in 1998, while diarrhoea / malnutrition deaths were more common in 1999. Having a safe water source greatly reduced the number of fatalities caused by diarrhoea and malnutrition. Having a smaller number of people living in one house was also found to be a protective factor against malaria and diarrhoea/malnutrition fatalities.
Gudo et al., 2016	Cross-sectional study to assess the prevalence of Rift Valley Fever Virus (RVFV) in febrile patients in southern Mozambique during and after the 2013 floods and severe rains	The Maputo area was greatly affected by heavy rainfalls between January to March 2013, which resulted in flooding. The study was conducted a primary health care centre, the Mavalane Health Centre. Patients who were over 5 years of age and had febrile illness were invited to take part in the study. A total of 375 patients were enrolled, However, the final sample tested for anti-RVFV IgG was 200. Acute blood sample was taken from participants at enrolment and tested for malaria and RVFV serology was done in South Africa. Participants were required to return for a follow up sample collection three weeks later. A questionnaire was administered to gather demographic, epidemiological, clinical and RVFV risk factor information. Previous infection was defined by the presence of anti-RVFV IgG antibodies in samples. Acute infection was defined by the presence of IgM.	IgG anti-RVFV was detected in 20 (10%) of the samples. Ten (5%) samples had verified IgG anti-RVFV seroconversion. Most samples from patients with serological evidence of acute infections were collected from February to April. The existence of IgM anti-RVFV was also examined in the comparable acute sample from seroconverting individuals, and one (0.5%) was positive. Six out of 9 (67%) patients who fit the case criteria for acute RVFV infection were misdiagnosed as malaria and given antimalarial treatment. Samples from ten patients with serological evidence of acute RVFV infection were tested and found to be negative by real-time PCR. A total of 36 of the 375 individuals enrolled tested positive for malaria, resulting in a 9.6% prevalence rate. There was no evidence of RVFV and malaria co-infection in those individuals. Patients were divided into three groups based on their serological profiles: (1) acute RVFV infection if they seroconverted for anti-RVFV IgG antibodies between the acute and convalescent samples (5%); (2) previous RVFV exposure if anti-RVFV antibodies were present in both the acute and convalescent samples (5%) and (3) no anti-RVFV antibodies (90%). The most prevalent clinical manifestations were chills and stomach ache. There were no severe cases documented, and no patients had neurological signs, haemorrhages, or blindness.
Lopez-Carr et al., 2016	Ecological study to assess how climate-related vegetation changes affect the health status of children in sub-Saharan Africa,	Precipitation data was obtained from the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) dataset. Normalised Difference Vegetation Index (NVDI) was obtained from the NASA Global Inventory Monitoring and Modelling System (GIMMS) dataset. These datasets were integrated with cluster level information from the Demographic and Health Surveys (DHS) for Burundi,	The climate-exposure factors were significantly associated to child undernutrition in the Lake Victoria Basin (LVB). Increased rainfall was shown to have a significant positive relationship with child stunting (p-value <0.05). Increased vegetation index was shown to have a significant negative relationship with child stunting (p-value <0.05). Furthermore, it was shown that child stunting vulnerability is higher in locations with a significant rise in rainfall over time, particularly in the LVB's Northern and South-eastern regions in Tanzania and Kenya. In contrast, the vulnerability of child stunting

		Kenya, Rwanda, Tanzania, and Uganda. Modelling of <5-year-old stunted children was performed. The number of households from DHS between 2008-2012 was 95 500 (n= 856 clusters). Undernutrition was defined as extremely low height for age (also called stunting). The number of undernourished children <5-years was aggregated from household cluster level. The percentage of children in each cluster was calculated. Childhood stunting prevalence was then mapped using kriging.	was shown to be lower in the LVB regions that experienced the least change in vegetation index. Overall, locations that saw an increase in rainfall combined with a decrease in vegetation index were shown to be more vulnerable to climate-related child stunting.
considering the location of the child.			
Makanga et al., 2019	Retrospective cohort study investigating the place-specific factors (taken from literature and Delphi consensus) associated with maternal and perinatal outcomes in southern Mozambique. This study was part the feasibility study for the Community-level Interventions in Pre-Eclampsia (CLIP) trial aimed at reducing maternal and perinatal morbidity and mortality.	Purposive sampling and snowballing technique to select focus group discussion (FGD) participants from the CLIP trial. Ten FGDs were carried out in 4/12 clusters. The groups consisted of pregnant women, women of child-bearing age, birth attendants, male partners, community leaders and health workers. Historical contextual information was obtained through semi-structured interviews with 12 administrative chiefs from the study area. A total of 50 493 households, with 80 483 women between the ages of 14-49 years were included. A structured questionnaire, based on extensive research, was then developed. Variables included, obstetrics, epidemiology, demography, environmental health, geography, health equity, health research, medical anthropology, spatial statistics and mobile health. Contextual variables were collected from household census. The census collected information on women who were pregnant 12 months before the census, women of reproductive age who died, age, education, pregnancy history, and community factors. Classification of the cause of deaths (maternal, foetal and perinatal) were followed by verbal autopsy. Using flood and precipitation records from the previous year, flood-proneness was determined. The difference between the road quality indicator (RoQI) score on a day in the dry vs. wet season was calculated.	From a total of 80 483 women identified in the census, 14 617 were pregnant 12 months before the census. Only 9 172 (61.6%) had completed their pregnancy. In the total sample, there were 18 deaths. Verbal autopsy showed that 38% was from direct causes and 62% was from indirect causes. There were 288 miscarriages, 466 stillbirths, 8796 live births with 117 neonatal deaths. The highest rates of the outcome were observed in Ilha Josina+Calanga, Mazivila and Chissano. The study found that an increase in the degree of isolation increased the rates of adverse outcomes (p<0.05). There was significantly more isolation in the Magude, Ilha Josina and Calanga areas. There were higher rates of negative outcomes in communities with weak and flood prone road infrastructure a year before data collection (p<0.01). Areas most affected by precipitation and flooding were Josina+Calanga, Mazivila and Chaimite. Better outcomes were associated with improved access to proper sanitation (p<0.001), family support (p<0.05) and average age of women (p<0.001). Rates of adverse outcomes were negatively associated with fertility rates (p<0.001).
Nosrat et al., 2021	Cohort study to determine how extreme rainfall and temperature affect	The sample consisted of 7,653 children <18 years of age. Children spend lots of time outdoors during the day when mosquito vectors are actively breeding and biting. Monthly	DENV transmission was influenced by a multiplicity of factors. The region's climate extremes' such as rain and the land surface temperature had an impact on mosquito vector abundance in Kenya. Vector abundance was measured and sampled

		mean LST was extracted from Kenya's national aeronautics and space administration. Average monthly temperatures between 2013-2019, around the four selected locations were used. Datasets from the African Rainfall Climatology were used to assess rainfall variability from the coastal study sites of Msambweni and Ukunda and the western sites of Kisumu and Chulaimbo. Blood samples were assessed from children with acute febrile illness. Blood samples were tested for traces of viremia. Cases of Dengue virus (DENV) were further validated by polymerase chain reaction (PCR) testing and immunosorbent assay. If a child tested negative during a PCR test, he/she was not included in the total study population as this negative test meant that they had DENV previously.	according to certain life stages of a mosquito. Extreme weather such as floods significantly increased the odds of mosquito egg/ovitrap abundance being classified as "high" by 1280%. This was further supplemented by contrasting droughts that occurred in the Western study sites of Kisumu and Chulaimbo, which decreased the odds of overlap abundance by nearly 13%. These results were measured via a two-month lag period, with floods having a positive deviation from the standard rainfall in Kenya and extreme drought displaying a negative deviation. Between 2014 and 2017, 150 (51.5 %) of 291 participants with dengue viremia were malaria smear positive in a study of undifferentiated fever in Kenya, indicating a large overlap in infections. Binomial regression analysis showed that two-month lag of rainfall and LST severity, month and year were not significantly associated with DENV transmission. In mulinomial model, flooding significantly increased the odds of high egg abundance by 1280% when site, month, year, and LST classification were constant (OR=13.8 [6.5,29.3], p<0.001). Heatwaves reduced the odds of low (OR=0.32 [0.23,0.44] p<0.001), and high egg abundance (OR=0.22 [0.20,0.23], p<0.001)
mosquito abundance and the risk of dengue infection in a group of Kenyan children.			
Okaka and Odhiambo, 2019 (a)	Cross-sectional study assessing the health vulnerabilities of families living in flood-prone informal settlements in Kenya's coastal city of Mombasa, as well as their adaption strategies.	The study participants were randomly drawn from three purposively selected informal settlements in Mombasa City's Ziwa la Ng'ombe, Moroto, and Bangladesh. The participants in the research were the household heads who lived in informal settlements for at least three years. Questionnaires (n=390) were used to ascertain health vulnerability based on exposure, sensitivity and adaptive capacity. Six focus group discussions (FGDs) were used obtain information on participant health. The research also included interviews key informants with three public health officers and the county director in charge of disaster management.	Households had family members who were physically ill due to the floods but recovered in a few days (45.1%); who were ill but healed in 1-4 weeks (16.9%); and those who were ill but healed in >4 weeks or eventually died (8.7%). Most households (55.4%) were stressed due to the floods but felt better after 1-4 weeks and 5.6 % took longer (> 4 weeks) to recover from flood-related stress and required counselling. Females, adults ≥51 years, widowed, with no formal education, large household size, those with a close relative with chronic sickness or disability, and small traders were the most exposed to flood-related health effects. Housing, sanitation, and basic environmental factors were unfavourable, contributing to disease outbreaks. Some homes had trouble acquiring clean drinking water (>60%), requiring special measures (43.8%) or having no clean water (16.9%). Poor waste management and difficulty accessing healthcare were noted with 13.1% finding it difficult to fully access healthcare and 22.3 % having to put in extra effort by wading through flood water. Households needed to carry out additional work (>50%) or found it hard to work or could not do any work (13.1%). In all areas, households have been flooded at least three times in the previous 3-5 years (89.5 %). During the recent floods,, 49% of houses had water levels of 31-100 cm. Most residents (41.8%) had their homes flooded, with just 13.1 % having no flood water inside. Flooding harmed at least part of the assets of most families (85.4 %). Household flood vulnerability was ranked as high (40.8%), medium (46.9%) and low (12.3%).
Okaka and Odhiambo, 2019 (b)	Cross-sectional study assessing household perceptions of flood-	The study methodology is the same as Okaka and Odhiambo, 2019 (a) listed above.	. During the focus groups, participants expressed concern that flooding has grown so unexpectedly and has occurred more than three times in some years. According to the survey, 70% of the homes had a family member who became ill during the most

	related risks and health impacts in informal settlements from Mombasa		recent flooding. The most commonly occurring diseases were malaria (58.7%), diarrhoea (56.2%), skin infections (28.3%), typhoid (16.7%), and acute respiratory infections (9.1%). Aside from these, 70.3% reported other symptoms, including fever, headache, and coughing. Additionally, 80.8% of families had individuals who experienced stress during the previous flooding. According to the FGDs, a lot of these people required psychiatric treatment since their experience was devastating, as they lost most of their valuables and were stranded when their homes were flooded.
Olanrewaju et al., 2019	Mixed method study evaluating the health impacts and management of flood disasters in Ajeromi-Ifelodun, Nigeria	An extensive literature review and data from Ajegunle (a community in Ajeromi-Ifelodun) was used to assess the flood disaster management over the past two decades. Additionally, analysis of primary data collected in one local government area was done. Five areas were purposively sampled based on areas that were most vulnerable to flooding events, having high population densities and widespread water-borne disease incidence. Questionnaires (n=280) were distributed to a total of 56 residents from five neighbourhoods. Perceptions regarding flood were obtained from community members affected, including community leaders, school teachers, nurses, property owners, traders, and taxi drivers. On-the-spot assessments were carried out by volunteers (doctors, teachers, pharmacists, traders, and civil engineers).	The 2012 flood resulted in mortality due to diseases. Children <5 years and the elderly were particularly vulnerable. Questionnaire results showed that 47.1% of respondents suffered from cholera and dysentery. Flooding caused damage to sewage systems which resulted in contamination of food and water. Subsequently, 21.7% of typhoid cases were reported. Collection of stagnant water (from blocked drains, potholes, rivers etc) resulted in an 17.5% cases of malaria fever. Additionally, 4.3% of respondents experienced skin rashes from constant and prolonged contact with polluted water. Water polluted with rat urine resulted in 1.8% cases of Leptospirosis. Other diseases included hepatitis A (3.6%), hepatitis E (1.1%), Schistosomiasis (0.4%) and water-related infections (2.5%). Flooding prevented access to health care due to flooded roads, which isolated those in need from receiving assistance. An increase in the number of people migrating into the community resulted in an increase in the number of residents without access to governmental services. The community's vulnerability to the impacts of flooding is linked to poor infrastructure, overpopulation poor management of waste disposal and lack of access to health care.
Rieckmann et al., 2018	Ecological study exploring the association between extreme weather events (droughts and floods) and cholera outbreaks in Sub-Saharan Africa by determining the risk of cholera outbreaks during flood/drought periods compared to non-drought/flood periods	Population-level data for each country was identified from the EM-DAT International Disaster Database. Affected population were identified as those who were injured, affected and left homeless after a disaster. Drought was identified as a "long-lasting event" due to lack of precipitation and deficiency in a region's water supply. Flood was identified as a significant rise of water level in a stream, lake, reservoir, or coastal region. Flood and drought events were recorded if there was a high impact. Start and end dates were mostly provided by the database. Missing data was accounted for. An extended exposure period was created to account for delays in disease presentation. A cholera outbreak is defined medically by the isolation of Vibrio cholerae of O1 or O139 serogroups and events	During the 21 years of follow-up within the 41 sub-Saharan countries, a total of 276 cholera outbreaks and 118 drought and 515 flood disasters occurred. Of those, 25 cholera outbreaks began during drought, 24 during flooding, and 10 occurred during a simultaneous drought and flooding event and 217 during flood/drought free periods (majority of outbreaks, 79%). A cholera outbreak was registered in one of every three droughts and one of every 15 floods. The number of cholera outbreaks per drought was 4.5 times larger than for floods (0.30 versus 0.06). Yet the incidence rate was much higher for floods than droughts (38 outbreaks compared to 1.1 outbreaks per weighted country year). The rates of cholera outbreak during drought were significantly higher 3 regions [EAST IRR =4.6 (2.9-7.2), Central IRR =10.2 (1.4-74.3) and South IRR = 6.0 (2.5-14.4)] compared to drought-free periods. For floods, the rates were significantly higher in all four regions compared to non-drought/flood period [East IRR=101 (59,-173), West IRR = 106 (49-228), Central IRR = 105 (278-,272) , and South IRR =210 (60-737)]. While there was an increased incidence rate of cholera outbreak during both drought and flood periods compared to drought/flood

			free periods ([IRR] = 4.3, 95% [CI] = 2.9-7.2 and IRR =144, 95% CI = 101-208 for drought and flood periods, respectively).
		registered as "acute diarrheal syndrome" and "acute watery diarrhoea" in EM-DAT.	Self-controlled case series the IRR of cholera outbreak for drought compared to drought/flood free was 5.37 (95% CI = 3.55-8.11) and flood compared to drought/flood free was 145 (95% CI = 97-217). Sensitivity analysis showed that drought had an IRR of 4.4 (95% CI = 3.1-6.3) and floods, an IRR of 216 (95% CI =148-314) when compared with drought/flood-free periods. Socioeconomic status as indicated by HDI was stratified, the analysis showed significant associations between droughts, floods and cholera outbreaks in each category per droughts in the highest HDI group. *Somalia was excluded from this analysis due to missing HDI data. The study has shown that cholera outbreaks in Africa have been attributed to both droughts and floods. However, the risk of a cholera outbreak is elevated during droughts and floods compared to drought and flood free periods.
Sara et al., 2018	Case-control study to investigate the risk factors associated with the suspected 2016 scabies outbreak in the East Badewacho District.	In the sample, 89% of homes reported flooding. Questionnaires containing sociodemographic questions, clinical features of scabies, treatment or management, ways of transmission and risk factors (family size, travel history, overcrowding, contact with an infected person, availability of water for hygiene purposes and history of flooding) were used. There were 3 categories for cases, [1] suspected case- a person with signs and symptoms of scabies including superficial burrows, intense itching, generalised rash and a secondary infection; [2] diagnosed case, a person who has had scabies identified by a healthcare professional and [3] a person who had no signs or symptoms of scabies but had had direct contact with a suspected or confirmed case in the previous 2 months (This would be prolonged, direct skin-to-skin contact for example).	Total of 4,532 cases of suspected scabies of which 58% were male. Flooding was a significant risk factor for scabies infections. The crude odds ratio (COR) differences between flood-exposed homes vs. control groups was 23.9 (CI 95% 9.24-61.84). The adjusted odds ratio (AOR) between flood-exposed homes vs. control groups was 22.32 (CI 95% 8.46-58.90; p = <0.0001). Multiple regression analysis was used to adjust for confounders. Age (<15 years), family size (>5 members), close contact with scabies cases, flooded homes were significantly associated with scabies infections. The AOR for developing scabies infection was 2.6 (CI 95% 1.31-5.22) in children <15 years, 2.63 (CI 95% 1.10-6.27) for families with more than 5 members and 22.32 (CI 95% 8.46-58.90) for households affected by flooding. Flooding often results in displacement, overcrowding and lack of hygiene practices, which could increase susceptibility to infections.
Tandlich et al., 2016	Case study to assess the microbial water quality and conduct bacterial enumeration of soils at the Medolino resort in Port Alfred, following the flooding that occurred in October 2012.	The study site was the five-star Medolino Caravan Park and Resort, which was affected by flooding on 20 October 2012 and was submerged in 2-3m of flood water and sewage. Microbial water quality assessment was done on flood and drinking water samples. The first sampling took place on the 19 November 2012, when water and sewage was pumped out from the resort. The second sampling took place on 15 January 2013. Municipal sample 1 and 2	Flood water samples were tested on the 19 November 2012. The concentration of E.coli was > 100000 CFUs/100 mL., Salmonella spp. was >150000 CFUs/100 mL and Vibrio spp ranged from 6500 to >150000 CFUs/100 mL. Flood water samples tested on 15 January 2013 showed a decrease in E.coli concentration to 46500 CFUs/100 mL. and Salmonella spp. (50000-250000 CFUs/100 mL) and Vibrio spp. (1000 to 16500 CFUs/100 mL). In all four samples of drinking water taken on the 19th of November 2012, the concentration of E.coli was below 3 CFUs/100mL. The samples taken on 15 January

		were taken from drinking water taps in the tourists' chalets and sample 3 was taken from a private house. A control sample was taken from a municipal drinking water supply from a private house located outside the flood area. These sites are located where flooding occurred and sewage contamination from burst pipes was present. Bacterial enumerations for E.coli, Salmonella spp. and Vibrio spp. were done. During the post-disaster phase, fungal contamination of flood-affected chalets and houses was visible. Airborne fungal concentrations were measured. Mud samples were taken as well.	2013 was below 1 CFUs/100mL. This essentially means that there was no contamination of water supplies due to flooding. There was no contamination of water samples with Salmonella spp. and Vibrio spp. On 19 November 2012, the E.coli soil concentrations was 33-330 CFU/g. The Salmonella spp. and Vibrio spp. concentrations were 1 CFU/g. On the 15 January 2013, soil concentrations of E.coli was 1-3 CFU/g and Salmonella spp. was 4 to 22 CFUs/g and this showed that the concentration of Salmonella spp. was not affected by flooding. Vibrio spp. was not detectable in the soil samples. Mud samples taken from flooded houses tested positive for fungal contamination (16820 to 28540 CFUs/m3). This is indicative of a concentration high enough to cause negative respiratory health effects.
Taukeni et al., 2016	Cross-sectional study to determine the impact of extreme flooding on school children in the Oshana region, Namibia, by assessing the prevalence of post-traumatic stress disorder after a 2-year period.	The International Federation of Red Cross and Red Crescent Societies (2011) described the 2011 Namibian floods as some of the worse experienced by the country in a decade. Children from 14 schools, between the ages of 8 -18 years old, were included in the study (n=429). To assess the prevalence of post-traumatic stress symptoms experienced by learners 2 years after the experience of severe flood a self-administered Child Trauma Screening Questionnaire (CTSQ) was used. The questionnaire was comprised of close-ended questions which contained items that assessed re-experiencing (5 items) and hyper-arousal (5 items). Children were required to respond yes/no to the experience of any one item listed in the questionnaire, which sought to assess the symptoms of trauma. The test was administered by professional social workers/educational psychologists who would be able to identify any signs of distress in the children.	Younger children, compared to older children, had a lower proportion of having bad dreams (45% vs.53.5%), having flashbacks (50.7% vs. 61.3%), experienced thoughts and memories (75.3% vs. 77.6%), sleep problems (26.8% vs. 38%), were grumpy or lost their temper (47% vs. 56%), became upset by reminders (78.7% vs. 84.7%), poor concentration (34.7% vs. 36.9%), hypervigilance (68.9% vs.80.4%) and irritability (82.8% vs. 89.6%). Only the proportions of physical symptoms were higher in younger children compared to older children (35.1% vs. 28.1%). A mean cut-off score of 5 or above on the trauma screening questionnaire is considered a predictive indicator for PTSD. In summary, female young children had a mean score of 5.37 and older children a mean score of 6.33. Male young children recorded 5.43, while older males reported 5.84. According to this study, a total of 55.2% and 72.8% of the younger and older learners, respectively, reported experiencing symptoms of trauma from the floods 2 years post-disaster. In terms of distribution, the most common score for young children was 4 (19.4%) followed by 6 (17.1%), indicating that younger children appear to display fewer symptoms of trauma. The most common CTSQ score for older children was 7 (21.3). However, this effect was small with only 2% of variance being accounted for by age.
Zamand and Hyder 2016	Cross-sectional study assessing the impact of drought and excessive rainfall/flood on child human capital across Ethiopia, India, Peru and Vietnam.	The study included children between the ages of 14 and 16 years who were part of the Young Lives longitudinal research project on childhood poverty. The sample consisted of 2991 children from Ethiopia (840), India (874), Peru (537) and Vietnam (740). The experience of drought and flooding was based on self-reports by households. Health outcomes were determined using anthropometric indicators of nutritional status i.e., Body Mass Index for age	In Ethiopia, 30% of children live in households affected by drought and 13% affected by floods. The school enrolment rate was 90%. The long-term health of adolescents is adversely affected by the shock, resulting in a fall in the HFAz-score by 0.56 standard deviations. Floods, droughts and other agricultural shocks, could potentially significantly reduce investment in child nutrition. In the sample, 15% of children were underweight and 28% moderately underweight. Ethiopia had the highest thinness; with 12% of children being severely stunted and 17.6% moderately stunted. Children were moderately stunted with a mean HFA z-score of -1.41. Droughts and flood had

| (BFA) and Height for Age (HFA) z-scores. BFAz-scores are defined as the measure of weight relative to height, adjusted for child age and sex. HFAz-scores are defined measures of height adjusted for age and sex. Additionally, schooling abilities were tested using the one quantitative ability measure, school enrolment and three cognitive tests which were the (1) (Peabody Picture Vocabulary Test; (2) Math Test score and; (3) Cloze test score. | significant impacts on PPVT and Mathematics scores. PPVT scores were reduced by 2.9 point and 6.7 points for drought and floods, respectively. In 2009, drought reduced PPVT scores for younger children in the Young Lives samples. In Ethiopia, there was no evidence that rainfall variability affected schooling. |

6.2.2   Temperature Table

Table 6.3 Temperature

Author name(s) and year of publication	Study population and design	Methods	Findings
-center: **TEMPERATURE/EXTREME HEAT/HEAT WAVE STUDIES**			
Abed and Matzarakis 2017	The objective of this study was to analyse, in a sophisticated way, the climate conditions in different regions of Algeria related to health and tourism. These regions are represented through selected cities considered among the most urbanised and populated of the country.	• The thermal conditions of the bioclimate was investigated by applying the physiologically equivalent temperature (PET) seasonal variability of five main Algerian cities representing different climate and geographical conditions • The PET calculated for this study at 12.00 UTC (13.00 local time) • This study is important since it is performed for the first time in Algeria using a deterministic approach through the calculation of PET based on the body-atmosphere energy balance using the Munich Energy-Balance Model for Individuals (MEMI).	• The study shows a significant increase in the number of days with strong and extreme heat stress within the last three decades.
Aissa 2019	Time series analysis investigating the influence of weather conditions on the onset of Spontaneous Pneumothorax (SP) in the Region of Sousse (Tunisia).	• Data on weather conditions were collected daily throughout the 5-year period. • Medical data included information on pneumothorax (occurrence, number, location, recurrence and evolution), age, sex, smoking status and medical history of each patient. • SP was measured in two ways; the occurrence of one or more episodes pneumothorax for a given date and count data which measured the number of episodes per	• The study found a correlation between clusters of spontaneous pneumothorax and weather conditions in the region of Sousse-Tunisia. • A comparison of the mean temperature between days with and without SP showed significantly higher temperatures during the days with SP. • SP was significantly associated with the seasons with the highest number of cases occurring in Summer (61 cases) and Spring (50 cases). Autumn had 47 cases and only 30 cases occurred in winter. There was a higher risk for developing SP during summer compared to other seasons

		day. If the period between two episodes of SP was ≤3 days, it was defined as a cluster.	• A decrease of 1% in the relative humidity one day lag (D-1) was associated with an increase in the risk of SP by 1.6%. • The occurrence of clusters was significantly associated with higher temperature averages on the same days. • This same observation was made regarding the mean duration of sunshine two days before the cluster onset. • The occurrence of storms two days before clusters was also significantly associated with a risk multiplied by 1.96.
Asamoah et al., 2018	Qualitative study investigating the association between maternal heat exposure during pregnancy in hot regions and an increase prevalence of spontaneous abortions or stillbirths in Ghana	• Data on miscarriages and stillbirths were obtained from the 2007 Ghana Maternal Health Survey (GMHS) • A separate questionnaire was administered to a subsample of women aged 15-49 years. • Information of maternal health history and health care issues were collected. The sample comprised of 1136 women. • Heat exposure levels was determined using the wet-bulb globe temperature (WBGT)	• Majority of the women in the sample were young (mean age 22.9 years), lived in rural areas (54%), and had low level of education. About 12% of the latest pregnancies ended in either miscarriage (9.6%) or stillbirth (2.8%). • The analyses of the four selected regions indicated 27 to 42% increase in the odds of experiencing miscarriage or stillbirth with every degree increase in wet-bulb globe temperature (WBGT). • Environmental heat exposures may be associated with adverse pregnancy outcomes, but this study was inconclusive, possibly because the heat exposure range was small.
Baker, 2020	Cross sectional study Investigating the effect of ambient temperatures and child nutrition in Sub-Saharan Africa	• Anthropometric data was taken from the Demographic and Health Surveys for 192,000 children from 30 countries in Sub-Saharan Africa was combined with historical climate data to directly estimate the effect of temperature on key malnutrition outcomes. • The average temperatures were then calculated for the month of the survey, the 12 months before the survey, and the entire lifetime of the children.	• There is a strong negative relationship between child weight and average temperature across regions. • Increased temperatures in the month of survey, year leading up to survey and child lifetime led to meaningful declines in acute measures of child nutrition • Increased temperatures in the year preceding up to the survey had the greatest impact in rural areas, where weight-for-height and weight-for-age ratios dropped dramatically when temperatures rose beyond 25C • The study found that the lifetime-scale effects explain most of the region-level negative relationship between weight and temperature, indicating that high temperatures may be a constraint on child nutrition. • The study used CMIP5 local temperature projections to project the impact of future warming and found substantial increases in malnutrition depending on location: western Africa would see a 37% increase in the prevalence of wasting by 2100, and central and eastern Africa 25%.
Bishop-Williams et al., 2018	Retrospective cohort study investigating the association between all-cause hospital admissions and local meteorological parameters to inform climate change planning	Satellite database of weather conditions in partnership with researchers from the European Centre for Medium-Range Weather Forecasts Re-analysis (ERA)-Interim Climate Database. Extreme values were defined as extremely high (> 95th percentile) and extremely low (< 5th percentile). Meteorological parameters including temperature, precipitation and seasonal variability. Including max, min and average as well as extremely high and extremely low values. Hospital admission records	A total of 41,216 hospital admissions were recorded at the community clinic during the study period. Majority of children were female (54.6%) and majority adults (56%) were male. Adults between 19-55 constituted most intakes. Most common diagnoses for adults were malaria, trauma, and acute gastrointestinal illness while for children, the three most common diagnoses were malaria, trauma, and acute gastrointestinal illness (notably climate-sensitive diseases). Admissions were higher in dry season than rainy season (except 2014). Rate of admissions for all diagnoses was significantly higher when temperature was extremely high (> 95th percentile and equating to 22.3 - 29.7 C) on day of admission. One extremely warm day, average

| | | obtained from Bwindi community hospital included age, sex, diagnoses, admission date, and treatment ward. All hospital diagnoses are made according to the Ugandan Clinical Guidelines National Guidelines for Management of Common Conditions. Outcome variable was admissions per day over a constant denominator (non-migratory population therefore the number of people eligible to use hospital services remained unchanged). | daily admissions increased from 37.1 to 43 patients per day. Therefore, hospital admissions were 1.16 times higher during extreme high temperatures.

Average daily temperature increased each year from 2011 to 2014 (average daily temperature was 17.9C in 2011; 18.1C in 2012; 18.5C in 2013; and 18.6C in 2014). While average daily total rainfall varied less than 1 mm from 2011-2014 with no significant trends over time. |
|---|---|---|---|
| Bunker, 2017 | Case series analysis investigating the association between heat exposure and years of life lost (YLL) from non-communicable diseases (NCD) in Nouna, Burkina Faso, between 2000 and 2010. | • Temperature data for Nouna was taken from the National Climatic Data Centre
• Due to missing data, the hourly mean (t-mean), maximum temperature (t-max) and minimum temperature (t-min) was obtained
• The sample size comprised of 18 367 NCD-YLL corresponding to 790 NCD deaths recorded in the Nouna Health, and Demographic Surveillance Site register over 11 years. | • Premature death from NCD was elevated significantly with moderate and extreme heat exposure.
• Daily average NCD-YLL were 4.6, 2.4 and 2.1 person-years for all ages, men and women, respectively.
• Moderate 4-day cumulative rise in maximum temperature from 36.4°C to 41.4°C resulted in 4.44 excess daily NCD-YLL for all ages, rising to 7.39 at extreme temperature (42.8°C).
• Exposure to cooler temperatures was associated with more prominent health effects for all-ages and for women. Interestingly, only women had a statistically significant increase in mean daily NCD-YLL with extreme cold. |
| Dapi et al., 2010 | Cross-sectional study providing a description of environmental conditions in schools assessing the impact of heat on the health of school children during school days. | Three public secondary schools were randomly selected in Yaounde (School 1 and 2) and Douala (School 3). The total sample consisted of 258 children aged 12-16 years. The classrooms had no water, electricity and air conditioning. There is tap water available in the schoolyard. Windows are sometimes made by creating a box-like opening in the wall. The floors are made of cement and the roof is made of tile or cement. Six students sit at a desk, which is arranged in rows of six.

The study team (a public health expert, two nurses and four university students) administered questionnaires to students. Background information on age, sex and general symptoms were recorded at the beginning of the week. Questionnaires on feeling hot were administered at the end of the week. Only 50 children were interviewed for student performance. Students were asked about symptoms and performance on Monday to Thursday. Students were asked to recall all symptoms of the previous day. | The mean body temperature overall was 37.6C; with 30 children in Yaounde having a temperature of 38 C. Three different groups of children, from schools 1-3, were used in this study. Children reported symptoms of fatigue (75%), thirst (62%), headaches (49%), slept in class (36%), felt very hot (31%) and felt very hot in the head (20%). Girls have a higher percentage compared to boys for sickness, thirst, fatigue, vertigo, malaria, headache, very hot overall, hot in the head and sleeping in class.

In schools 1 and 2, the study found a significant positive association between indoor air temperature and the percentage of the following symptoms; feeling hot, fatigue and headaches. In Yaounde these symptoms increase with an increase in indoor area temperature during the day. Comparisons within a day (12:30am vs. 15:30pm) showed that headaches (r=0.53) and feeling hot (r=0.72) was associated with indoor temperature. This was more evident for school 1 on the hottest days during week. The highest proportions for feeling hot (48%), fatigue (76%) and headaches (38%) in Yaounde was observed on March 24th, 18th and 23rd, respectively. During the day, schoolchildren's performance declines. In Yaounde, being absent minded was 62%, writing speed decreases in 45% of participants and 25% did not understand the lessons.

Daily indoor and outdoor air temperature and dew points, from the morning to the afternoon, increases. The highest outdoor daily temperatures for Yaounde and |

		Indoor temperature, humidity, and dew point were measured in the classrooms using a Lascar datalogger. The datalogger was installed in the classroom's roof corner. A Celsius thermometer was used to monitor the daily indoor temperature and relative humidity at the Douala school. Furthermore, outdoor temperatures were monitored with a Celsius thermometer which was positioned across the shade of a window and connected to an outside wire (also in the shadow).	Douala was 33.6C and 35.6C. The highest indoor temperature for Yaounde was 32.5C and 36.6C for Douala.
Egondi et al., 2015	Time-series analysis aimed to (1) assess the association between temperature and years of life lost (YLL) in two informal settlements in Nairobi (Korogocho and Viwandani); (2) assess the effects of cold spells and heat waves on YLL; (3) provide information on the burden of weather extremes on vulnerable populations who simultaneously face health and socio-economic problems.	Weather data was recorded at the Moi Airbase Eastleigh and the Jomo Kenyatta International Airport (JKIA) weather stations, which are located between the two study sites. For the study period (2003-2013) daily mean, minimum and maximum temperatures were taken. Extremes are defined based on the relativity of weather to the normal weather in the area and temperature for the season. The heatwave percentiles used were 90th, 95th and 98th. The percentiles used for cold spells were 10th, 5th and 2nd. A 2-day duration of heat wave and cold spells were considered for analysis. Mortality data for both slums was taken from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) for a period where whole data was available. A total of 66000 from both slums were under surveillance by 2012. Information on birth date, enumeration, migration patterns in and out of the study areas, sex, age, death date, cause of death and exit were recorded. The daily YLL was calculated by calculating all the deaths that occurred within that day. The data was also separated into age and sex to estimate the YLL for each death. The study used distributed lag nonlinear models to assess the effect of daily temperature and total YLL across lag dimensions. A 14-day lag was used to assess the delayed effects of temperature and mortality and a 21-day lag was used to evaluate the sensitivity of the results.	During the research period, 4671 fatalities were documented in the NUHDSS, with an average of 1.3 deaths each day. The daily average number of deaths did not differ significantly by gender or age group. Males, on the other hand, died at a higher rate 2651 (56.8%) than women 2020 (43.2%). There was 56.6 YLL per day owing to all causes of mortality throughout the research period, totalling 206,712 YLL. Continual exposure to an average temperature of 30C for 14 days, a shift from the reference temperature of 26C, resulted in an increase of 3.3 YLL in a given day. As a result, the cumulative relationship between temperature and YLL in the research region did not reveal a substantial heat effect. Low temperatures were shown to have a significant relationship with YLL, which rose as the intensity computed relative to the median temperature throughout the cold spell days increased. 53.2 YLL was connected with the median temperature for days with temperatures below the 2nd percentile (20C) of 18 C. A loss of 23.7 years was connected with a median temperature of 21C for the least rigorous definition of days determined by temperature below 10th. From all this it was concluded that exposure to ambient temperature change is linked to YLL owing to all causes of mortality in Nairobi; and notably, cold temperatures appeared to be more dangerous. When looking at age groups the age group with the highest mortality was 25-50 years (n=1966), followed by; 0-5years (1487), then 50 plus years (657), then 15 -25 years (415), lastly the least number of deaths were among the age group of 5 to 15 years (146).

Faye et al., 2021	Ecological study to assess the most suitable heat wave definition among 15 different ones and to evaluate its impact on total, age-, and gender-specific mortality for Bandafassi, Senegal	• Daily mortality data was taken from the Bandafassi Health and Demographic Surveillance System (HDSS) • Daily weather station data were obtained from Kedougou situated at 17km from Bandafassi from 1973 to 2012. • This study used 15 types of definitions of heat waves (by combining thresholds and durations) • Poisson generalized additive model (GAM) and distributed lag non-linear model (DLNM) were used to investigate the effect of heat wave on mortality and to evaluate the non-linear association of heat wave definitions at different lag days, respectively.	• Heat wave definitions, based on three or more consecutive days with both daily minimum and maximum temperatures greater than the 90th percentile, provided the best model fit. • The study found that females and people aged ≥ 55 years old were at higher risks than males and other different age groups to heat wave related mortality. • The impact of heat waves was associated with total-, age-, gender-mortality.
Gates et al., 2019	Case-crossover study investigating the association between daily ambient temperature and homicide incidence in South Africa	• Mortality data was obtained from South Africa's civil registration system and included all recorded deaths in the country from 1997 to 2013 (17 years), across 52 districts. • Daily temperature was taken from the National Oceanographic and Atmospheric Association of the United States and South Africa's Agricultural Research Council. • Data was analysed using a time-stratified case-crossover design. • Cases were delineated as either "definite" or "probable" homicides. • Analyses investigated same-day and lagged effects of maximum, mean and minimum temperature.	• There is a positive association between daily ambient temperature and homicide in South Africa. • A 1°C increase in same-day maximum temperature was associated with a 1.5% increase in definite homicides and a 1.2% increase in total (definite + probable) homicides. • The odds of homicide were 18% higher when same-day maximum temperatures were 30-35°C compared to temperatures below 20°C • The effect of maximum temperature was higher in males than in females. • This temperature-health relationship may be of particular concern in the context of climate change, especially in the absence of short-term adaptation.
Helman and Benjamin 2020	Cross sectional study assessing whether temperature anomalies affect violent conflicts in African and Middle Eastern warm regions by conducting a systematic longitudinal analysis spanning the entire African and the Middle Eastern (ME) regions for the 1990-2017 period	• A systematic regional and grid-based longitudinal analyses was performed, using geolocated information on armed conflicts and a recently released satellite-based gridded temperature dataset. • Monthly maximum temperatures were taken from the Climate Hazards Center Infrared Temperature with Stations (CHIRTS) data set • Information on violent conflicts were obtained from the most recent Georeferenced Event Dataset (GED)	• There is seasonal synchronicity between temperature and number of armed conflicts at the regional scale (climatic region), as well as a positive relationship in temperature and conflict anomalies on inter-annual timescales at the grid cell level (for the entire African and ME region). • After controlling for location effects, the study did not find that long-term warming has affected armed conflicts for the last three decades. This means that violence was indifferent to the long-term change in temperature. • Therefore, changes in violence were not affected by warming or cooling trends in the analysis period. However, the effects of temperature anomalies are stronger in warmer places (~5% increase per 10°C, P <0.05), suggesting that populations living in warmer places are more sensitive to temperature deviations. • Taken together, these findings imply that projected warming and increasing temperature variability may enhance violence in these regions, though the mechanisms of the relationships still need to be exposed.
Kim et al., 2019	Time series analysis examining the short-term	• A two-stage meta-analysis was conducted.	• A total of 1 320 148 suicides were included in this study.

	temperature-suicide relationship using daily time-series data collected for 341 locations in 12 countries for periods ranging from 4 to 40 years	• First, a location-specific time-stratified case-crossover analyses was performed to examine the temperature-suicide association for each location. • Then, a multivariate meta-regression was performed to combine the location-specific lag-cumulative non-linear associations across all locations and by country	• The study showed that the risk of suicide increased with increasing ambient temperature in many countries, but to varying extents and not necessarily linearly • A non-linear association (inverted J-shaped curve) was observed with the highest risk at 27°C. • In South Africa, 39 cities were included in this study, with a suicide count of 5,128 (0.08%). Suicide in males was 77.9% and 94.5% in people <65 years old. Suicide levels plateaued or reduced when temperatures were extremely high, in populations are accustomed to high temperatures
Lokotola et al., 2020	Case cross-over study investigating the effect of temperature on air pollution and the subsequent association with cardiovascular disease (CVD) hospital admissions in South Africa.	In this study, a total of 54 818 (22 914 females and 31 904 males) hospital admissions for cardiovascular disease (CVD) were included. The age groups were 15-64 years (n= 27 225) and >65 years (n= 27 095). CVD hospital admissions were defined using the International Classification of Disease [ICD-10] (I00-199). Individual-level data was taken from seven private hospital and electronic databases. Air pollution variables studied included PM10, NO_2 and SO_2. Air pollution monitors provide continuous real-time concentrations of the pollutants. These monitors measure the pollutant concentrations in ten second scans using sensors and the measurements are sent to the Air Quality Monitoring Laboratory. Averages were calculated using daily 24h measurements from specific monitoring sites.	On warm days, there were large and significant correlations between CVD hospital admissions and air pollution compared to average or colder days. On average, 10g/m3 increases in NO_2 and SO_2 were shown to have higher correlations than PM10. On warm days, there was a significant effect modification for PM10, specifically for all ages and the 15–64-year-old group. This indicates that during hot days, the risk of PM10 is much higher than on regular days. Furthermore, on warm days, the impact of NO_2 was significantly altered in people of all ages. For the 15–64-year-old group, however, the impact of SO2 was much larger on cold days than on normal days, despite the risk being higher on warm days. In general, the 15–64-year-old group was more at risk for CVD hospitalization on hot and cold days due to higher air pollution levels than all ages combined or the 65-year-old group. With rising PM10 levels, females seemed to be at greater risk than males. Males, on the other hand, were more sensitive to the impacts of NO_2 and SO_2 than females.
Scovronick, 2018	Time-series regression analysis study analysing the association between temperature and mortality in South Africa using a national dataset that includes all 8.8 million recorded deaths between 1997 and 2013 across 52 district municipalities	• Temperature data was taken from the National Oceanographic and Atmospheric Association (NOAA). • All recorded deaths were obtained from the South African civil registration system. • Mortality and temperature data were linked at the district municipality level and relationships were estimated with a distributed lag non-linear model with 21 days of lag and pooled in a multivariate meta-analysis.	• The study found an association between daily maximum temperature and mortality. • There are mortality burdens associated with cold and heat, and the young and elderly as particularly vulnerable • The relative risk for all-age all-cause mortality on very cold and hot days was 1.14 and 1.06, respectively, when compared to the minimum mortality temperature. • This was evident for every age and cause group investigated, except among 25–44-year-olds. • The strongest associations were in the youngest (< 5) and oldest (> 64) age groups and for cardiorespiratory causes. • Heat effects occurred immediately after exposure but diminished quickly whereas cold effects were delayed but persistent. • Overall, 3.4% of deaths (~ 290,000) in South Africa were attributable to non-optimum temperatures over the study period.
Tusting et al., 2020	Cross-sectional study assessing the direct	• Data were extracted from 52 Demographic and Heath Surveys, dating from 2003 to 2016, that recorded	

	causal relationship between high environmental temperature and child growth faltering in 29 sub-Saharan African countries	anthropometric data in children aged 0–5 years, and were linked with remotely sensed monthly mean daytime land surface temperature for 2000–16. • The sample comprised of 656 107 children • The odds of stunting, wasting and underweight relative to monthly mean daytime land surface temperature were determined	• Monthly mean daytime land surface temperature above 35°C was associated with increases in the odds of wasting, underweight, and concurrent stunting with wasting, but a reduction in stunting compared with a monthly mean daytime land surface temperature of less than 30°C. • This decrease in was seen more in children 2- years (0,89, 0,83-0,95; p=0,00081) compared to children >2 years old (0,92, 0,85-0,99; p=0,034). • Children aged 0–5 years living in hotter parts of sub-Saharan Africa are more likely to be wasted, underweight, and concurrently stunted and wasted, but less likely to be stunted, than in cooler areas.
Wichmann, 2017	case-crossover study investigating the association between daily ambient apparent temperature (Tapp) and daily all-cause non-accidental mortality in Cape Town, Durban and Johannesburg during a 5-year study period (2006-2010)	• The associations were investigated with the time-stratified case-crossover epidemiological design. • Models were controlled for PM_{10}, public holidays and influenza epidemics. • City-specific Tapp thresholds were determined using quasi-Poisson generalised additive models. • The pooled estimates by sex and age groups were determined in meta-analyses. • The city specific Tapp thresholds were 18.6°C, 24.8°C and 18.7°C, respectively for Cape Town, Durban and Johannesburg	• A 3.3%, 2.6% and 2.8% increase in mortality per inter-quartile range (IQR) increase in Tapp (lag0-1) was observed in Cape Town, Durban and Johannesburg, respectively above the city-specific thresholds. • The elderly was more at risk in Cape Town and Johannesburg • No difference in risk was observed for males and females in the three cities. • In the meta-analysis, an overall significant increase of 0.9% in mortality per 1°C increase in Tapp (lag0-1) was observed for all age groups combined in the three cities. • For the ≥65year group, a significant increase of 2.1% in mortality was observed.
Wilde et al., 2017	Ecological study investigating whether increases in ambient temperature during conception, while in utero, or after delivery, impact adult educational and health outcomes in sub-Saharan Africa.	The study used census data from 2000 and 2014 for six sub-Saharan African countries from Demographic and Health Surveys (DHS), Malaria Indicator Surveys (MIS), and AIDS Indicator Surveys (AIS). Samples are drawn from geographical clusters. The study focuses on unborn children (infants from 6 months before conception and to 3 months after birth) educational attainment, literacy, and disability in adults. The data contain detailed information on the health of children and women as well as household characteristics. Using this data the effect of temperature at conception on mortality is investigated, as well as specific channels which may be driving the correlation between temperature and outcomes. Weather data was taken from the University of Delaware. The study used the gridded temperature dataset from Willmott and Matsuura (2012). The temperature shocks are measured in absolute value from the mean in order to better estimate the variance of these shocks.	There was no systematic evidence that temperature shocks before, during, or after conception have any effect on disability status. Temperature shocks during the time of conception have also been demonstrated to have no effect on the mortality of infants once they are born. Temperature at the time of conception is positively correlated with the first measure of educational outcomes. Educational attainment and literacy rise for individuals who were conceived during periods of elevated temperatures. Temperature may induce different groups of women to become pregnant at different times, either intentionally or unintentionally and may also affect fecundity heterogeneously for women of different socioeconomic groups. It was found that individuals conceived during hot temperatures had better educational achievement and literacy. Evidence of temperature impacts in utero at other periods, particularly during the first trimester was also discovered. Temperature spikes at the time of conception are associated with better educational attainment and literacy. Children born in winter are more likely to have a mother who is a teenager, have low education, or be single. Weather shocks affect crop failures. Crop failure negatively affects nutritional intake over the course in mothers. Temperature extremes during conception and early pregnancy were linked to higher human capital outcomes later in life.

| Wright et al., 2019 | Cross-sectional study assessing the association between heat and the socioeconomic, infrastructural and health risk factors in the city of Johannesburg. | A total of 480 questionnaires were distributed but only 136 household questionnaires were included (n= 580 individuals). These were given to parents of school children who were participating in a larger project. Self-reports were split into doctor diagnosed, and other perceived symptoms. The included heat-related health symptoms included sweating, weakness, fatigue and dizziness, and muscle cramps. The doctor-diagnosed chronic health conditions included hypertension and stress, followed by skin rash/dermatitis and any chronic injuries. An amended questionnaire was used and were arranged in a hierarchical manner; (1) demographic information and heat symptoms of each household member; (2) household data. Heat wave periods were determined by SA Weather services. Johannesburg experiences frequent heat waves. The highest temperature recorded in January 2016 was 38C and 36.5C in November 2015. | In this sample, the heat-health effects reported were sweating (35.8%), headache and nausea (19.1%), weakness, fatigue and dizziness (15%), muscle cramps (10.3%), hot, dry and flushed skin (7%), shallow breathing (6%), irregular heartbeat (5.6%), agitation and confusion (4.6%), Cold, pale and clammy skin (4.6%), increased respiratory rate (4.6%), fainting (3.6%), weak rapid pulse (2.5%), shock (2.2%), decreased level of consciousness (2%), seizures (1.8%), any other symptoms (1.8%) and cardiac arrest (1.0%)

The study found that age was a significant risk factor for adverse health effects associated with heat. Compared to other age groups, those who were over 60 years had twice as likely to experience any heat associated health effects Gender also showed variations in health effects with females being 1.15 times more likely to suffer from health effects associated with heat. However, this result was not statistically significant. Hypertension was found to be statistically significantly associated with heat exposure. Those who had hypertension were two times more likely to experience adverse health effects due to heat. Most families lived in detached houses, flats/apartments, and RDP houses. Houses had tiled and corrugated iron rooves. Most households have access to electricity, piped water and a toilet inside the house. Less than 10% of the homes had an air conditioner. Living in an RDP houses and those with asbestos sheets was also associated with heat-health effects. |

6.2.3 Cyclones/Storms Table

Table 6.4 Cyclones and Storms

Author name(s) and year of publication	Study population and design	Methods	Findings
Calgaro et al., 2020	Descriptive analysis report to analyse the Neonatal Intensive Care Units (NICUs) evacuation plan and care at Beira Cental Hospital during	The study is based on Beira Central Hospital located in Beira, Mozambique. This country is regarded as one of the most vulnerable countries to extreme weather events and it is a low resource setting. The sample consisted of 13 sick neonates aged 1- 28 days neonatal care unit (NICU) and 17 stable neonates in the Kangaroo Mother Care	The cyclone caused major disruptions to water and electricity supplies. Therefore, the incubator and radiation lights meant to keep the babies warm, did not work. Strong winds blew a portion of the roof off and rain entered the NICU and as such the babies had to be moved to the KMC unit where mother helped to keep the additional babies warm in sheets. During the evacuation, a pre-term baby suffered hypothermia and died soon after. There were no cardiopulmonary machines and only one oxygen

		(KCU) unit. Despite a week notice of the impending cyclone, there was no emergency plan put into place.	machine available. Medical archives were destroyed. Babies were moved by hand to the paediatric intensive care unit (PICU) and had to share beds and oxygen machines.
and after cyclone Idai in Mozambique.			
Cambaza et al., 2019	Short communication based on available documents aimed at tracking the spread of Cholera infection in areas affected by cyclone Kenneth, describing the public health interventions by governments and future recommendations.	The study used population-level figures based on secondary data. The Saffir-Simpson scale was used to determine a category 3 hurricane. Additional meteorological information came from United Nations Office for the Coordination of Humanitarian Affairs. Epidemiological data was codified using an adapted strategy from the Public Health Agency of Canada. Including, context, outbreak identification, process of investigation, interventions and descriptive epidemiology. Total number of cases and transmission rates were recorded in four areas based on 1. population density. 2. Proximity to Pemba (capital city). 3. Previous history of outbreaks.	Cyclone Kenneth caused significant damage and a cholera outbreak. However, this was well managed compared to other severe weather episodes possibly due to experience gained from previous episodes resulting in improvement in healthcare, proper sanitation and better hygiene practices. Pemba recorded the highest number of total cases (approximately 200), the fastest transmission rate, and highest cumulative attack rate of 98.7 per 100,000 residents. By 28th May approximately 275 cases of cholera had been recorded across the four areas. Metuge and Mecufi both recorded less than 50 cholera cases in the same period, transmission was higher in Metuge. The 4th area, Ibo did not register any cases presumably due to their physical distance away from Pemba. The number of new cases began to decline after 5th May. No fatalities due to cholera were recorded by 31st May (a vaccination programme beginning on 16th May have contributed). Additional health issues such as malaria, food insecurity, death of family members and loss of housing were mentioned as additional concerns (although no data was recorded).
Devi, 2019	News reporting to describe the conditions which existed in areas that were affected by cyclone Idai in Mozambique in 2019	According to the United Nations, cyclone Idai was noted as the deadliest storms in the southern hemisphere. The cyclone resulted in massive flooding, with communities being submerged in close to 10m of water. Roads and infrastructure were severely damaged. Weeks after cyclone Idai struck Mozambique, thousands of people were isolated and cut off from rescue and aid. The cyclone caused major destruction with the corridor from Mozambique to Malawi, Zambia and Zimbabwe being damaged. This resulted in a disruption in trade, supplies of fuel, wheat and other necessities.	Approximately 3 million people were affected, with 239731 houses destroyed (112745 were destroyed, 111202 partially destroyed, and 15784 flooded). The cyclone resulted in over 1000 fatalities: 602 deaths in Mozambique, 344 in Zimbabwe and 59 in Malawi. Many people were living in temporary settlements and left those without access to safe water and proper sanitation. When a cholera outbreak was declared on 27 March 2019, 4979 cases and six deaths were reported by the 12th of April 2019. A vaccination campaign was launched by the World Health Organization (WHO). Over 800 000 cholera doses were distributed. There was a notable increase on the risk of malaria occurring due to receding waters providing a suitable breeding environment for mosquitoes. Other health concerns included skin infections, measles, pneumonia and mental health disorders. Disruption of health care services impeded the treatment of existing diseases such as tuberculosis, diabetes and hypertension. According to UNAIDS, 1.8 million people are HIV-positive in Mozambique, with 24% being prisoners. In 2016, 54% of those affected were using antiretroviral therapy. Since 2010, HIV prevalence decreased by 24% and AIDS-related mortality decreased by 46%.
Lequechane et al., 2020	Cross-sectional study reporting on the cholera epidemic in Mozambique following Cyclone Idai	On the 14th of March 2019, a category 4 cyclone, cyclone Idai, struck five provinces in Mozambique resulting in heavy rains, severe flooding and strong winds. A State of emergency was declared on 19th of March. The Sofala	Mozambique was struck by cyclone Idai in 2019 resulting in substantial damage. Household were completely (n= 122 700) or partially damaged (n=111 200). The subsequent death toll from cyclone Idai was 603, affecting 1,8 million people. Approximately 400 000 residents were displaced and were accommodated in

		province was the most affected with the inhabitants of the districts already living in extreme poverty, having limited access to safe water and proper sanitation. On 27 March 2021, a cholera outbreak occurred. The Ministry of Health (MoH) established a task force and surveillance system to monitor and report on the outbreak of infectious diseases. One-step rapid Cholera diagnostic tests were used for identification of cholera strain. Positive samples were sent to the laboratory for further testing. A paper-based surveillance was used to identify clinical characteristics and diseases which included fever, cholera, diarrhea and malaria. Following this a cost-effective Early Warning Alert and Response System (EWARS) was developed. Participants who used EWARS were enrolled in this study. EWARS was rolled out to 67 health facilities in the 4 most-affected districts.	shelters, have little access to basic services. A total of 6768 suspected cholera cases were registered by 21 April 2019. The attack rate was recorded as 571/100 000 habitants with 8 deaths occurring (case fatality rate: 0.12%). Areas most affected in Sofala Province were Beira (n=533 825 habitants), Dondo, Nhamatanda (n=317 538 habitants) and Buzi. A reduction in cholera cases was noted following WASH interventions and mass oral cholera vaccination (OCV) campaigns. Over 800 000 people were vaccinated from the most affected districts in the Sofala province.
and describe the emergency measures taken to control the spread of infectious diseases.			
Meierrieks 2021	Cross-sectional study exploring the relationship between short-term weather shocks, long-term climate change, and national health outcomes for a sample of 170 countries from 1960 to 2016.	The participants included in this study was selected using health data extracted from the World Development Indicators (WDI). The following criteria were utilized for participant selection: (1) child health using infant mortality; (2) health of economically active adults in the population using adult mortality rate and (3) overall population health using life expectancy. Data on climate variables are drawn from the Climate Research Unit of the University of East Anglia. Collection of two climate variables took place within this study: (1) temperature in degrees Celsius and (2) precipitation depth in 1000 millimetres. This study also made use of climate data from previous years, for example, in countries such as Serbia and Turkmenistan climatic data was made available from the 1960s, 1970s and 1980s.	Higher temperatures are significantly associated with adverse health outcomes. Precipitation was not found to be associated with adverse health outcomes. When other health determinants, such as wealth, was accounted for the results show that richer countries have better health outcomes. A 1 ^{0}C rise in the population-weighted country-average temperature was associated with an increase in infant mortality by 1.76/1000 live births and a decrease in life expectancy by 0.31 years Changes in precipitation does not affect health outcomes, irrespective of country wealth. Higher temperatures are associated with adverse health outcomes, in pooper countries. A 1 ^{0}C increase in temperature in poorer countries was associated with an increase in infant mortality by 2.25/1000 live births and an increase in adult mortality rate by 9.36 A 1 ^{0}C increase in temperature in these countries was also associated with decrease in life expectancy by 0.47 years.
Pozniak et al., 2020	Correspondence article exploring how continuity of care for treatment of HIV was interrupted after	Mozambique has the eighth highest prevalence of HIV in the world. Beira, the capital city of the Sofala province, where hurricane Idai predominantly made landfall, reports 1 in 6 adults having HIV. When hurricane Idai hit some	Community based healthcare workers involved with the programme tripled in just one week following the hurricane. The original number of health workers was 70 and this increased to 237 people who had all received training in the delivery of emergency response in natural disasters.

| cyclone Idai. Additionally, to discuss the efficacy of the Geracao Biz programme continued care of persons with HIV (SAAJ) through community-based services. | 850,000 people in Beira were affected, 146,000 were internally displaced, over 500 were killed and many more injured. Health services were interrupted. This posed a major challenge to the continuity of care for persons living with HIV. Cell phones and GPS tracing was used to collect field data in rapid time following the disaster. | The number of persons living with HIV who were contacted and monitored by field workers in the 6-month period following the hurricane was 4500 which prevented disruption in HIV care for patients. A year after the cyclone struck, the health facilities remain committed to ensuring care of HIV patients. In many regions impacted by natural disasters, adequate preparedness can ensure HIV services are maintained in the face of disasters. |

6.2.4   Flood/Precipitation + Temperature Table

Table 6.5 Flood Precipitation and Temperature

Author name(s) and year of publication	Study population and design	Methods	Findings
Anyamba et al., 2012	Ecological study examining how recent outbreaks of two mosquito-borne diseases, chikungunya and Rift Valley fever, across Africa and the western Indian Ocean basin islands are associated with specific climate anomaly patterns	• This study mapped disease location data on corresponding NDVI and climate data anomalies to understand associations between climate variables and disease outbreak patterns through space and time. • The study further illustrated the lag time between the driving climate conditions and the timing of first case for Rift Valley fever. • For chikungunya, the researchers further investigated the relationships among surface air temperature, precipitation anomalies and disease outbreak • For Rift Valley fever they further investigated relationships between precipitation and disease outbreak.	• Above-normal rainfall, cooler-than-normal temperatures, and above-normal vegetation development were strongly associated with the ecology of Rift Valley fever outbreaks. • Drought and warmer-than-normal temperatures were associated with chikungunya epidemics in the greater East African region. • Extremes in climate conditions forced by the *El Niño*/Southern Oscillation (ENSO) lead to severe droughts or floods, ideal ecological conditions for disease vectors to emerge, and may result in epizootics and epidemics of Rift Valley fever and chikungunya. • However, the immune status of livestock (Rift Valley fever) and human (chikungunya) populations is a factor that is largely unknown but very likely plays a role in the spatial-temporal patterns of these disease outbreaks. • As the frequency and severity of extremes in climate increase, the potential for globalization of vectors and disease is likely to accelerate.
Apantaku et al., 2013	Qualitative study investigating the effects of climate change on health of rural households in the Ijebu North-East	• The heads of households (n=120) were selected using multistage and random sampling techniques.	• The major climate changes noted in this study were a change in rainfall patterns (73%), increased rain volume (53%), prolonged drought in the last few years (74%), increased dry season (73%), unstable temperatures (74%), increased sunshine intensity (52%) and the late appearance of harmattan.

	Local Government Area of Ogun State, Nigeria	• A structured interview guide was used to obtain primary data from the households on their personal characteristics and health status. • Data on the climatic elements such as sunshine intensity and duration, rainfall, and the mean temperatures from 2007 to 2011 were obtained from the Nigerian Meteorological Agency (NIMET) Station Ijebu-Ode office. • The data collected were subjected to both descriptive and inferential analyses.	• The major health problems reported to be associated with climate change included the common cold, cough, malaria, and fever due to climate change. • Data analysis revealed that climatic change has significant effects on respondents' health status. • The study concluded that there have been changes in the climatic pattern in the area and the health status of the people were affected.
Ayanlade et al., 2020	Ecological study assessing the impacts of climate indices on the spatio-temporal distribution of malaria and meningitis (MM) in Nigeria, in efforts to develop an Early Warning System (EWS)	• Cumulative rainfall anomalies, Satellite-derived Africa Rainfall Climatology (ARC) to examine rainfall patterns • This comprised of retrieved satellite observation, including aerosol optical depth, precipitation, minimum and maximum temperature from January 2000 to December 2018. • Data from the Ethiopian Demographic and Health Survey (DHS), a nationally representative nutrition and health information survey for women between 15-49 years and children under 5 years.	• The Climatic Index with the most considerable influence on the appearance and spread of malaria is precipitation. • With regard to meningitis, temperature and aerosol are the most significant climate indices. • There is a strong positive relationship between rainfall and malaria, in Mangrove swamp and freshwater, respectively in the south and a moderate association in the north. • There is a weak positive relationship between rainfall and meningitis in all ecological zones. • This data indicates that rainfall does not have a significant influence on meningitis transmission. The relationship between malaria and temperature is positively weak, in Sudan and Mangrove. In the Sahel, Sudan and Guinea, meningitis has a strong correlation with temperature.
Azage et al., 2017	Retrospective cohort study investigating the effect of climate variability on childhood diarrhoea (CDD) and identify high risk periods of diarrheal diseases in north-western parts of Ethiopia.	• Surveillance data on children under 5 years, with diarrhoea, were extracted from the Health Management Information System at the district level • Incidences of cases were compared to estimated children's population size based on 2007 National Population and Housing Census of Ethiopia (i.e., population considered at risk). • Data of the different climate conditions were extracted from the satellite data	• The study found a positive association between monthly average temperature and childhood diarrhoea. • A negative association was noted for rainfall and relative humidity and childhood diarrheal incidence. • Diarrheal diseases incidence increased from Feb (14.4 per 1000) and peaked in June (17.1 per 1000). The pre-rainy season had the highest average disease incidence. This suggests that the period of high risk was between March and June 2014, with East Gojjam reporting approximately 4838 cases in that period. • A total of 217,734 cases of diarrhoea were reported during study period. A slight majority of disease incidence among male children (55.5%).

Azongo et al., 2012	Time series analysis assessing the association of daily temperature and precipitation with daily mortality by age and sex groups in the Kasena-Nankana Districts of Northern Ghana, from 1995-2010.	• Mortality data was obtained from the Navrongo Health and Demographic Surveillance System (NHDSS) • Daily minimum and maximum temperatures and daily precipitation data, from January 1995 to December 2010, was obtained from Navrongo Meteorology Station. Short-term daily weather lags were used to assess the association between climatic variables and mortality. • The HDSS monitors births, deaths and migrations and the data was separated according to age and sex	• A linear relationship is observed for precipitation and daily mortality. Between 1995 to 2010 a total of 31 144 mortality reports were included, with 52.4% being males and 47.6% being female. • In the study population, short-term increase in precipitation was positively associated with mortality, with 10mm precipitation increase associated with 1.7% at lag days 2-6. For children <5 years the risk of mortality was higher with increasing lagged day. • The area witnessed a decline in all-cause mortality over the five years. Most deaths occurred in people 60+ (34.9%) while the highest maximum daily deaths occurred in children <5 years (11.0).
Chirebvu et al., 2016	Retrospective study investigating clinical malaria transmission patterns and its temporal relationship with climatic variables in Tubu village, Botswana	• A 5-year retrospective time series data analysis was conducted to determine the transmission patterns of clinical malaria cases at Tubu Health Post and its relationship with rainfall, flood discharge, flood extent, mean minimum, maximum and average temperatures. • Data were obtained from clinical records and respective institutions for the period July 2005 to June 2010, presented graphically and analysed • Weather data was taken from Shakawe Meteorology Station, Gumare Agricultural Research Station and the Department of Water Affairs.	• Peak malaria season occurred between October and May with the highest cumulative incidence of clinical malaria cases being recorded in February. • The age group >5 years was identified as experiencing the greatest burden of clinical malaria. • Associations between the incidence of clinical malaria cases and several factors were strong at lag periods of 1 month; rainfall (r = 0.417), mean minimum temperature (r = 0.537), mean average temperature (r = 0.493); and at lag period of 6 months for flood extent (r = 0.467) and zero month for flood discharge (r = 0.497). • The effect of mean maximum temperature was strongest at 2-month lag period (r = 0.328). • Maximum temperature was not associated with the incidence of clinical malaria cases.
Chuang et al., 2017	The specific aims of this study were to assess the impact of short-term climatic variations on malaria transmission and identify specific areas vulnerable to climate conditions that promote transmission in Swaziland.	• Malaria case-surveillance data was provided by Swaziland's National Malaria Control Programme. • Climate data were derived from local weather stations and remote sensing images. • The weather stations were in the four major administrative regions; Hhohho, Manzini, Lubombo, and Shiselweni • The data was analysed using seasonal autoregressive integrated moving average models and distributed lag non-linear models (DLNM).	• The incidence of malaria in Swaziland increased between 2005 and 2010, especially in the Lubombo and Hhohho regions. • A time-series analysis indicated that warmer temperatures and higher precipitation in the Lubombo and Hhohho administrative regions are conducive to malaria transmission • DLNM showed that the risk of malaria increased in Lubombo when the maximum temperature was above 30 °C or monthly precipitation was above 5 in. In Hhohho, the minimum temperature remaining above 15 °C or precipitation being greater than 10 in. might be associated with malaria transmission.

Codjoe et al., 2020	Qualitative study exploring health system vulnerabilities related to floods and excessive heat in Accra and Tamale, Ghana, as well as measures for resilience building by care providers and community members.	• Eighteen health care practitioners from 16 health facilities including public and private clinics, hospitals, and pharmacies were interviewed. • Semi-structured questionnaires. • All interviews were transcribed and analysed. • The deductive approach was used for analysis, utilizing the notions of resilience and vulnerability.	• Healthcare equipment and supplies were affected which affected health care operations. For example: stand-by generators at health facilities became unusable during extreme flooding or fuel to run them was unavailable. • Flood events increased mental health problems which led to an increase in demand for both physical and mental health services. • Extreme heat disrupted infrastructure, affecting drug storage and water access due to disruption to infrastructure during extreme heat. • Disruption of water and electricity supplies due to associated low rainfall, power outages, and increased energy demand. • Some of the smaller health facilities which deliver outpatient services faced additional problems e.g., carrying water to the primary health centre, which does not have a piped supply on site, becomes harder during extreme heat.
Colon-Gonzalez et al., 2016	Ecological study investigating the short-term effects of air temperature, rainfall, and socioeconomic indicators on malaria incidence across Rwanda and Uganda from 2002 to 2011	• Clinically diagnosed malaria cases for both countries were taken from the Ministries of Health and the HEALTHY FUTURES data sharing Consortium Agreement. • In Rwanda, malaria data were collected at the health facility level and aggregated to district level based on map coordinates for each facility. • In Uganda, malaria data was collected from the Ministry of Health, Health Management Information System. • This was district level data and the 2002 geographic distribution was used.	• The findings show that trends in malaria incidence agree well with variations in both temperature and rainfall in both countries, although factors other than climate seem to play an important role. • The estimated short-term effects of air temperature and precipitation are nonlinear, in agreement with previous research and the ecology of the disease. • The average monthly crude incidence rate (CIR) was low, with a case number of only 5/1000 people. This could be due, in part, to the high altitude of Rwanda which is approximately 1800m above sea level. On the other hand, Uganda had a greater average monthly CIR of 39/1000 people. • The near surface air temperature in Rwanda and Uganda was 18-33°C and 20-41°C, respectively, which were conducive for the transmission of malaria. • The study found large geographic heterogeneity in malaria cases per 1000 people which could be due to various behavioural factors such as immunity, irrigation practices, access to window screening and proper use of diagnostic tools.
Diboulo et al., 2012	Retrospective analysis to investigate the association between weather patterns and daily mortality in the Nouna Health and Demographic	• Meteorological data from 2004-2009 were obtained from ten nearby weather stations in the Nouna. The daily weather data was aggregated from the hourly measurements to obtain the daily mean, maximum and minimum temperatures. The same was done with the rainfall measurements.	• The study found profound associations between higher temperature and daily mortality in the Nouna, Burkina Faso. • Most deaths occurred in people 60+ (34.9%) while the highest maximum daily deaths occurred in children under five years

	Surveillance System (HDSS) area during 1999–2009.	• HDSS was used to obtain mortality data on a daily basis • Time series Poisson regression models were established to estimate the association between the lags of weather and daily population-level mortality, adjusting for time trends.	• The short-term direct heat effect was particularly strong on the under-five child mortality rate. • A strong linear relationship was observed between rainfall events and daily mortality, particularly in elderly populations • The increase in mortality in lag 0-1 translates to a roughly 50% increase in mortality throughout the temperature range. Rainfall was not shown to be substantially associated to death in this group.
Dunn and Johnson 2018	Retrospective study using covariate-adjusted cluster analysis to assess the geo-spatial distribution of childhood diarrheal disease in 10 countries from West Africa, during the period 2008-2013, using data from Demographic and Health Survey (DHS)	• Data for the health outcome was obtained from the DHS and the sample then consisted of 115 811 children. • The temperature data came from the Climatic Research Unit (CRU) and rainfall data was obtained from Tropical Applications of Meteorology • A purely spatial scan statistic was applied, where the observed diarrhoea cases were modelled as a Poisson variable and were compared to expected cases predicted from non-spatial logistic regression.	• Covariate-adjusted cluster analysis detected a weak to moderate association between diarrhoea prevalence and all covariates except for rainfall. • The study found an overall diarrhoea prevalence of 12.8%. The highest prevalence was 19.6% in Senegal and the lowest was 6.0% in Benin. • The odds of diarrhoea were 80% higher in a desert setting than monsoonal areas. • Increase in temperatures showed a 22% increase in the odds of diarrhoea episodes occurring • Increased rainfall, compared to no rainfall, reduces the odds by 18%. However, at higher rainfall levels, the odds increase by 13%.
Egondi et al., 2012	Time series analysis describing the relationship between daily weather and mortality in Nairobi, Kenya, and to evaluate this relationship with regard to cause of death, age, and sex.	• meteorological data on rainfall and temperature were acquired from Kenya's Meteorological Department from 2003-2008. • Mortality data was taken from the Nairobi Urban Health and Demographic Surveillance System and applied time-series models was used to study the relationship between daily weather and mortality for a population of approximately 60,000 during the period 2003–2008 • A distributed lag approach was used to model the delayed effect of weather on mortality, stratified by cause of death, age, and sex.	• A total of 2 512 non-accidental deaths were recorded for the study period. The causes of death identified were HIV (25.2%), non-communicable diseases (12.5%), pneumonia (8.9%), acute infections (16.7%) and other causes (36.8%) • Increases in mortality were associated with both hot and cold weather, and rainfall in Nairobi, but the relationship differed with regard to age, sex, and cause of death. • Increasing temperatures were significantly associated with mortality in children and non-communicable disease (NCD) deaths. • Mortality among people aged 50+ and children under five years appeared most susceptible to cold compared to other age groups. • Rainfall, in the lag period of 0–29 days, increased all-cause mortality in general, but was found strongest related to mortality among females. • Low temperatures were associated with deaths due to acute infections, whereas rainfall was associated with all-cause pneumonia and NCD death.

| Grace et al., 2015 | Ecological study examining the relationship between birth weight, precipitation, and temperature in 19 African countries | • Data from 1986-2010 was taken from the Demographic and Health Surveys (DHS).

• Data on maternal variables and gave retrospective information about new-born health, including birth weights, at the individual level.

• Recorded birth weights from the surveys were matched with gridded monthly precipitation and temperature data derived from satellite and ground-based weather stations

• Observed weather patterns during various stages of pregnancy were also used to examine the effect of climate factors on birth weight | • The study found that climate impacts birth weight and at a level comparable, in some cases, to the impact of increasing women's education or household electricity status

• There was a negative association between hot days and birth weight. An increase in the number of hot days (above 100F) corresponds with a decrease in birth weight for any trimester. An extra hot day with temperatures above 100 F correlates to a 0.9g decrease in birth weight. A larger effect on birth weight is seen when temperatures are increased to 105F.

• A positive association between growing season precipitation and birth weight was recorded and higher amounts of precipitation showed larger birth weights, with results being significant for all trimesters. A 10 mm increase in precipitation corresponds to 0.3-5g increase in birth weight.

• When both climate variables are included in a regression model, the same effects on birth weights can be seen. The results are significant for hot days during trimester 1 and 2, precipitation before conception (trimester 0) and during trimester 1. This shows that low precipitation and high numbers of hot days significantly increases the likelihood of delivering a baby with a low birth weight. |
| Grace et al., 2021 | Retrospective analysis to investigate the differential pathways that connect climate/weather variability to child health outcomes in Mali | • Climate indicators designed to capture the complexities of different climate-related risks and isolate their impacts based the timing and duration of in utero exposure were used.

• The focus was on individual level infant birth weight with attention to local seasonal weather conditions associated with disease (malaria), heat stress, and food insecurity.

• Rainfall data was taken from the Climate Hazards Centre InfraRed Precipitation with Station (CHIRPS) and temperature data was taken from the Princeton University's Terrestrial Hydrology Research Group | • There is a link between birth weight and exposure to malarious months throughout the third trimester. A respondent's child's birth weight was higher when the mother was exposed to more malarious months throughout the latter stage of pregnancy.

• When it comes to malarious conditions affecting a new-born's sex, the risk of a female infant birth increases when the third trimester of a pregnancy has a higher proportion of malarious months. Earlier stages of pregnancy did not have a similar effect.

• Women who were exposed to higher malarious conditions after month 2 of pregnancy were more likely to have a non-live delivery.

• Therefore, through a selection process, malarious exposure has a favourable influence on birth weight.

• Heat stress in relation to birth weight- an infant is more likely to have a lower birth weight when exposed to more days over 100 °F during the third and first trimesters.

• Pre-term delivery or intrauterine growth restriction in a pregnant woman throughout these two trimesters might increase the chance of low birth weight. |

Heaney et al., 2019	Prevalence study assessing the connections between ENSO, local environmental conditions, and childhood diarrheal disease in Chobe District, Botswana	• The Botswana Integrated Disease Surveillance and Response (IDSR) Program collates children under 5 presenting with diarrhoea to health facilities • Weekly reports from January 2007 to June 2017 were extracted from 10 of the 16 healthcare facilities in Chobe District. • Daily minimum temperature and rainfall measurements were obtained from the Department of Meteorological Services • The Water Affairs Department in Kasane provided daily measurements of Chobe River height.	• La Niña conditions were associated with cooler temperatures, increased rainfall, and higher flooding in the Chobe region during the rainy season. • In turn, La Niña conditions lagged 0–5 months were associated with higher-than-average incidence of under-5 diarrhoea in the early rainy season. • Diarrheal risk in relation to temperature- for every 1°C rise on the warmest day of the concurrent week, a 3.64% increase in diarrheal illness was projected nationally. In the northern, central, coastal, and southern regions, each 1°C increase in maximum temperature was associated with a 1.45%, 1.87%, 5.74%, and 2.15% increase in diarrheal disease, respectively. • While the coastline region was least affected by increased precipitation, it had the highest link to rising temperatures. • Rotavirus transmission occurred exclusively from June to October and was found to peak during the cool, dry winter season in Botswana. • These findings demonstrate the potential use of ENSO as a long-lead prediction tool for childhood diarrhoea in southern Africa.
Horn et al., 2018	Ecological study investigating the short-term association between weather variables (rainfall and temperature) and diarrheal disease at a regional and national level, using 18-year data from different areas in Mozambique	• Weekly time series data for weather and diarrheal disease aggregated at the administrative district level for 1997–2014, was obtained. • Weekly disease cases were obtained from 141 administrative districts, from all public health facilities, in Mozambique • The Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) dataset was used to obtain the precipitation estimates and temperature data was taken from the Climate Research Unit (CRU)	• There is a strong association between diarrheal disease and precipitation- 1.04% (95% CI: 0.42, 1.66) rise in diarrheal illness counts for each additional rainy day over a four-week period • One additional wet day per week was associated with a 1.86%, 1.37%, 2.09%, and 0.63% increase in diarrheal disease in Mozambique's northern, central, southern, and coastal regions, respectively. • Diarrheal risk in relation to temperature- for every 1°C rise on the warmest day of the concurrent week, there was a 3.64% increase in diarrheal illness, nationally. • The coastline region was least affected by increased precipitation as it had the highest link to rising temperatures. • Diarrheal disease prevention efforts should target areas forecast to experience increased rainfall.
Ikeda et al., 2019	Contour analysis exploring the relationship between temperature, precipitation and diarrhoea case counts of hospital admissions	• The study visually examines simultaneous frequencies of anomalously high and low diarrhoea case counts occurring in a season and assigning colours to differences that were statistically significant.	• For adults, increased rainfall over longer periods of time resulted in higher hospital admissions for diarrhoea. • For adults, there were no statistically significant associations between temperature (Tmin and Tmax) and high and low anomalies in case counts of diarrhoea among individuals aged 5 years and older for any season.

	among vulnerable communities living in a rural setting in South Africa.	• The Nkhensani Hospital and Maphutha L. Malatjie Hospital provided handwritten admission data from January 2002-December 2016. • All diarrhoea cases were retrieved using criteria and phrases specified by a South African medical practitioner.	• The most statistically significant findings were for children under 5 years of age in whom there was a high prevalence of diarrhoea when conditions were either wetter than average during the rainy season or drier than average during the dry season, as well as when temperatures were higher than normal. • The results shown suggest that rainfall has a bigger role in disease transmission compared to the temperature. Children may be particularly vulnerable to diarrhoea transmission when conditions are very dry and hot.
MacVicar et al., 2017	Retrospective study investigating the association between meteorological factors and birth weight in a rural population in southwestern Uganda	• The study sample consists of 3691 women who gave birth at Bwindi Community Hospital in Kanungu District, Uganda, between June 2012 and June 2015. • The study targeted the Bakiga and Batwa ethnic groups • Linear regression was used, controlling for key covariates, to estimate the timing, strength, and direction of meteorological effects on birth weight.	• Precipitation during the third trimester had a positive association with birth weight, with more frequent days of precipitation associated with higher birth weight • Increases in average daily temperature during the third trimester were also associated with birth weight • When the sample was stratified by season of birth, only infants born between June and November experienced a significant associated between meteorological exposures and birth weight. • The association of meteorological variation with foetal growth seemed to differ by ethnicity; effect sizes of meteorological were greater among an Indigenous subset of the population for variations in temperature
Maystadt et al., 2015	Empirical analysis contributing to literature on the link between local variations in weather shocks and conflicts by focusing on a pixel-level analysis for North and South Sudan between 1997 and 2009.	• Data on conflict events was collected from the Armed Conflict Location and Event Dataset (ACLED). • The data specifies the exact location, date and other characteristics of conflict events based on news and reports within unstable states. • Climate data was taken from the University of East Anglia's Climatic Research Unit (CRU) Time Series (TS) dataset from January 1901. This provides average monthly temperature and precipitation.	• Temperature and rainfall shocks correlate with increased violence. • Violent conflict in relation to temperature- A one-standard-deviation rise in temperature anomalies is shown to increase the likelihood of violent conflict by 32%. The linear model was used to project the observed sequence of temperature anomaly realizations, and it was discovered that temperature changes may have influenced nearly a quarter (26%) of violent incidents in Sudan • Violent conflict in relation to rainfall/precipitation: Increased competition over natural resources, in particular water, is the main driver of increased violence in a region where pastoralism constitutes the dominant livelihood.
Mrema et al., 2012	Time-series analysis assessing the association between monthly weather (temperature and rainfall) on all-cause mortality by age in Rufiji, Tanzania, and to determine the	• The study uses longitudinal 11-year data from the Rufiji Health and Demographic Surveillance System (RHDSS) and collected information on population, health and important events.	• Over the 11-year period, a total of 10,116 deaths were recorded. • Rainfall anomalies drive malaria incidence • There was a significant rise in infant deaths due to weather shocks. Children and elderly are more sensitive to shocks. Decrease in monthly temperatures increased mortality in 0-4 age group (RR=0.934, 95% CI=0.894-0.974), 5-59

	differential susceptibility by age groups.	• Key informants from the communities were used to provide information on birth and deaths, following which, the households are revisited. • All cause mortality was grouped together according to age, gender and time lags. • Rainfall and temperature data was obtained from Tanzania Meteorological Authority (TMA) in Dar es Salaam.	age group (RR=0.956, 95%CI=0.928-0.985) and 60+ age group (RR=0.946, 95% CI=0.912-0.979). • Rainfall had the strongest association in the under 5 age group when considering both short- and long-term lags. Overall, 10mm rise in rainfall increased 1.4% mortality risk. • Age group 5 - 59 experienced more delayed lag associations suggesting that those outside this group (children and elderly) are more sensitive to weather related mortality.
Niles et al., 2021	Ecological study to to assess the association between weather variables (precipitation and temperature) and child diet diversity in 19 low and middle-income countries across Africa, America and Asia	• Datasets from Demographic Health Surveys were used to obtain information on diet diversity, health and socioeconomic factors from 2000 to 2013. • The responses for over 200 survey variables were normalized. • An individual diet diversity score (IDDS) was constructed based on the United Nations Food and Agriculture Organization • Survey data from 19 countries, and more than 107 000 children, coupled with 30 years of precipitation and temperature data, was obtained to explore the relationship of climate to child diet diversity while controlling for other agroecological, geographic, and socioeconomic factors	• The study found that higher long-term temperatures are associated with decreases in overall child diet diversity, while higher rainfall in the previous year, compared to the long-term average rainfall, is associated with greater diet diversity. • Examining six regions (Asia, Central America, North Africa, South America, Southeast Africa, and West Africa) individually, it was found that five have significant reductions in diet diversity associated with higher temperatures while three have significant increases in diet diversity associated with higher precipitation. • South-east Africa has a child diet diversity of 2.66 and Lesotho has a diversity of 1.80. In West Africa, increasing rainfall appears to counter-balance the effect of rising temperature impacts on diet diversity. • In some regions, the statistical effect of climate on diet diversity is comparable to, or greater than, other common development efforts including those focused on education, improved water and toilets, and poverty reduction. • These results suggest that warming temperatures and increasing rainfall variability could have profound short- and long-term impacts on child diet diversity, potentially undermining widespread development interventions aimed at improving food security.
Olago et al., 2007	Mixed method study to determine Lake Victoria Basin community's propensity to either adapt or be susceptible to cholera epidemics due to climate change.	An integrated approach of qualitative and quantitative techniques was compiled from climate, hydrology, socioeconomic and health data to determine a lake basin community's propensity to either adapt or be susceptible to cholera epidemics. This was supplemented by annual time series of maximum and minimum temperatures for Kisumu (Kenya), Kampala (Uganda), and Biharamulo (Tanzania).	• Cholera peaks in the Lake Victoria Basin coincided with the El Nino event years of the region- September (years 1982, 1992), October (year 1992), November (years 1982, 1992, 1997), and December (1982, 1992, 1997). • Climatic data from Kenya, Uganda, and Tanzania suggests an increasing trend in maximum (Tmax) and minimum (Tmin) temperatures in these sites. However, on the Tanzania side of the lake basin, there was a declining trend in temperatures.

			• The communities of all three sites were impoverished, relying primarily on selling agricultural produce. Formal employment that provides a consistent source of income is only available to a small elite, making up 8% (Kisumu), 23,7% (Kampala), and 12,7% (Biharamulo) of the populations respectively. • These changes in climatic conditions further exacerbated situations of food insecurity. In Kisumu (Kenya), 89.9% of households claimed that they experienced days of food shortages. • Temperature and rainfall shocks correlate with increased violence; timing of shocks influences this as agricultural periods are seasonal.
O'Loughlin et al., 2014	Ecological study assessing the effects of temperature and precipitation variability on the risk of violence in sub-Saharan Africa from 1980-2012	• The study used a large database of conflict events and detailed climatological data covering the period 1980–2012 • A multilevel modelling technique that allows for a more nuanced understanding of a climate–conflict link was applied.	• In this study, 72,451 conflict events from 42 sub-Saharan African countries were included in the analysis. • The level of conflict increased with an increase in extremely high temperatures, however, different types of conflict and different subregions do not show consistent relationship with temperature deviations. • Cold extremes decreased the levels of conflict. Precipitation estimates showed that reduced rainfall reduced the level of conflict, however, precipitation deviations, both high and low, are generally not significant. • Other factors such as existing conflict, socioeconomic status, proximity to national borders, location of city and political stability are more closely related to conflict than climatic anomalies (temperature or precipitation variations from normal).
Randell et al., 2020	Cross sectional study examining the relationship between weather (exposure to rainfall and temperature) and child stunting, as an indicator of nutrition status, in Ethiopia.	• Data from four rounds of the Ethiopia Demographic and Health Survey were linked to high-resolution climate data to measure exposure to rainfall and temperature *in utero* and during early life. • Precipitation data was obtained from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS). Temperature data from the Climate Hazards Center Infrared Temperature with Stations (CHIRTS max)	• Stunting and severe stunting in this sample was 54% and 28%, respectively and the mean HAZ was -2.11. • The study found that greater rainfall during the rainy seasons in early life is associated with greater height for age. • Higher temperatures *in utero*, particularly during the first and third trimesters, and wetter conditions during the third trimester, are positively associated with severe stunting, though stunting decreases with temperature in early life. • A child has a 25% chance of being severely stunted if the child experiences an average temperature in of 25C in the third trimester, and the probability increases to 53% at 35C.

_____

Thiam et al., 2017	Retrospective cohort study investigating the association between childhood diarrhoeal incidence and climatic factors in rural and urban settings in the health district of Mbour in western Senegal	• Monthly diarrhoeal case records among children under five years registered in 24 health facilities (15 in urban areas and 9 in rural) over a four-year period (2011-2014) was obtained. • Climatic data (i.e., daily temperature, night temperature and rainfall) for the same four-year period were obtained. • A negative binomial regression model was used to establish the relationship between monthly diarrhoeal incidence and climatic factors of the same and the previous month	• The study identified significant health-climate interactions. • Two annual peaks in diarrhoeal incidence were observed: one during the cold dry season and one during the rainy season. • There is a positive association between diarrhoeal incidence and high average temperature of 36 °C and above and high cumulative monthly rainfall at 57 mm and above. • Positive associations in the lagged models were found for high LST variability and high rainfall (IRR: 1.42, 95% CI: 1.16-1.75; IRR: 1.21, 95% CI: 1.01-1.45, respectively). • The association between diarrhoeal incidence and temperature was stronger in rural compared to urban settings, while higher rainfall was associated with higher diarrhoeal incidence in the urban settings.

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6.3 APPENDIX C: HVI WORKSHOPPED MATERIALS

The development of a feasible framework required extensive workshopping, working backwards from the outcomes we had scoped. We unpacked all of the health outcomes identified in our review, while keeping in mind the literatures on HVIs related to each weather event. As such, we developed a number of frameworks that were workshopped over a six-week period among the team, and then workshopped through focus groups and interviews for another two months to provide you these updated draft frameworks.

6.3.1 Flood Framework Details

(see Figure 6 in text for the overview framework):
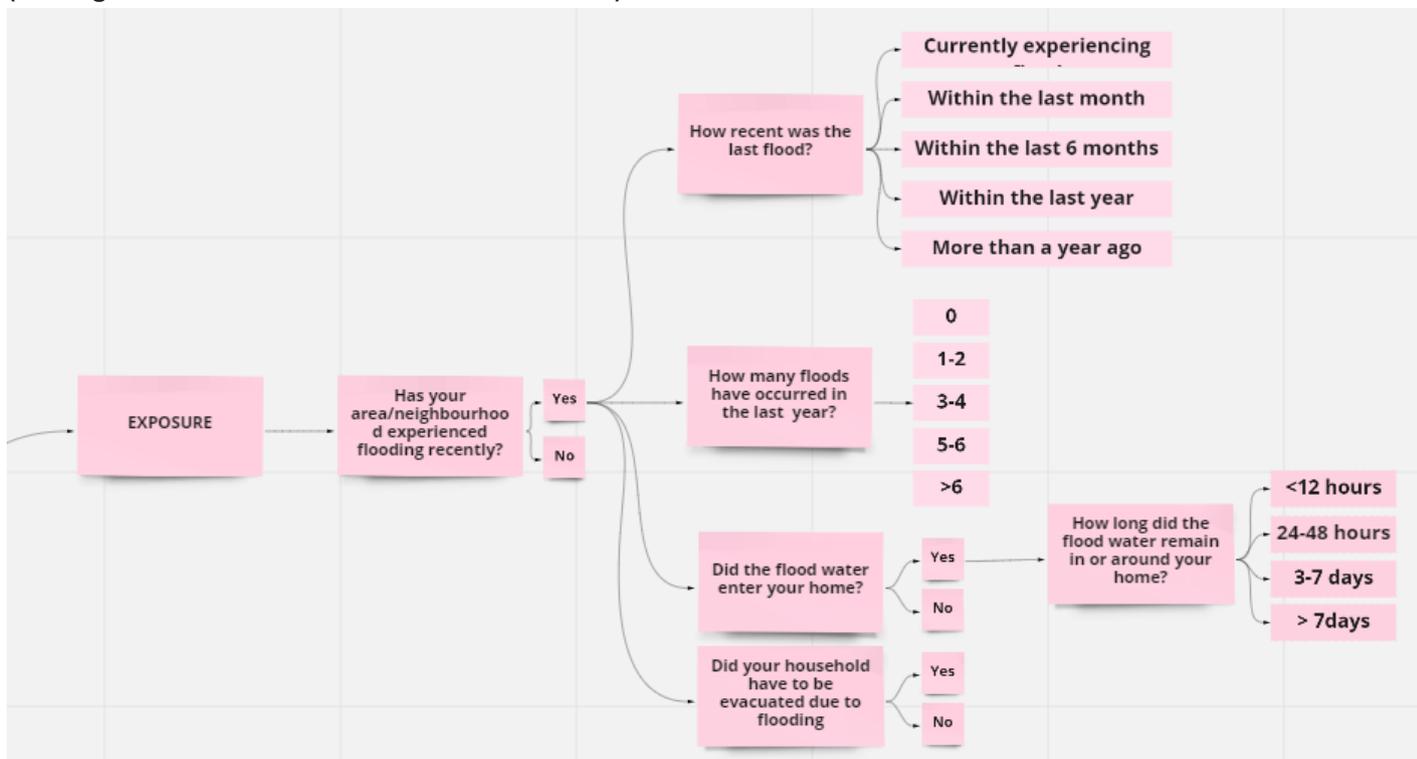
Figure 9: Flood Flow, Exposure
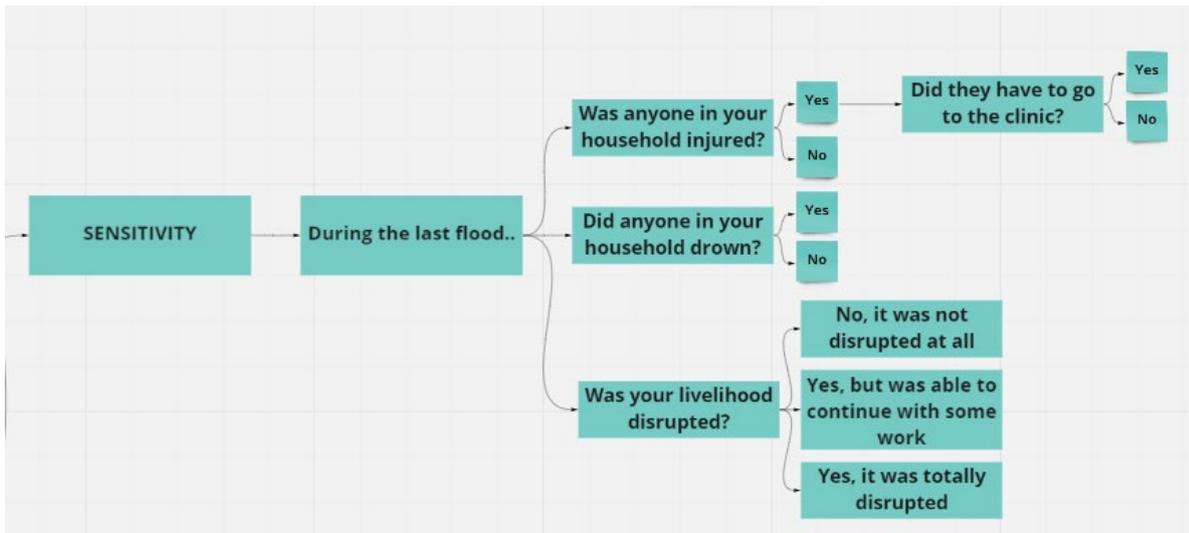
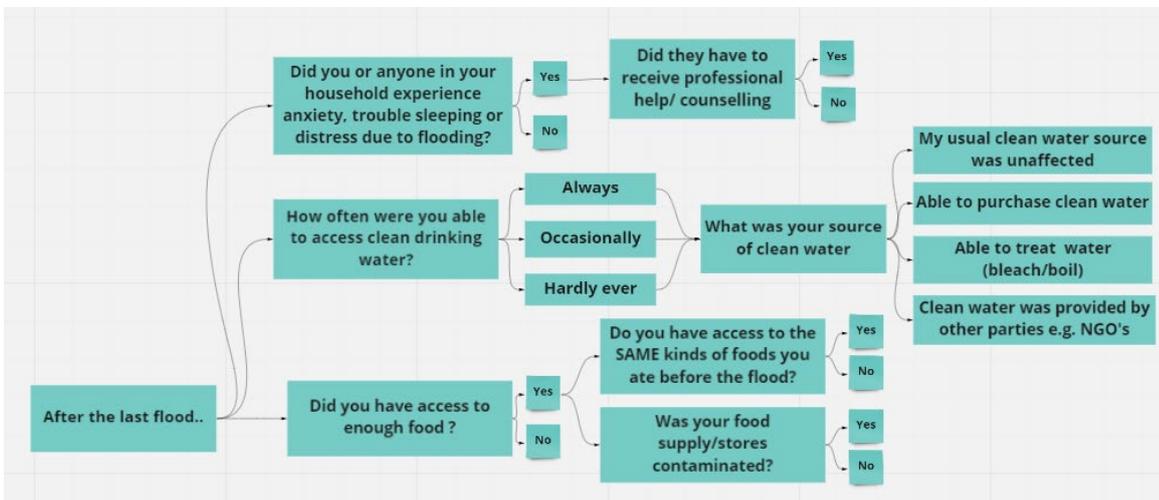**Figure 10: Flood Flow; Sensitivity during**
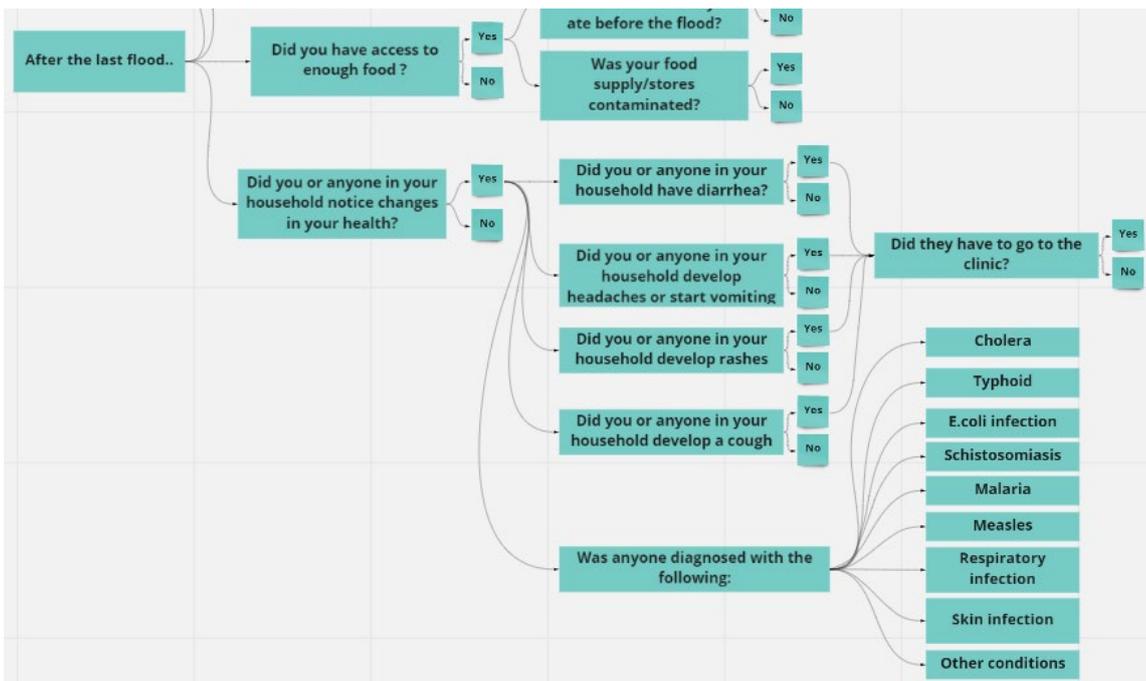
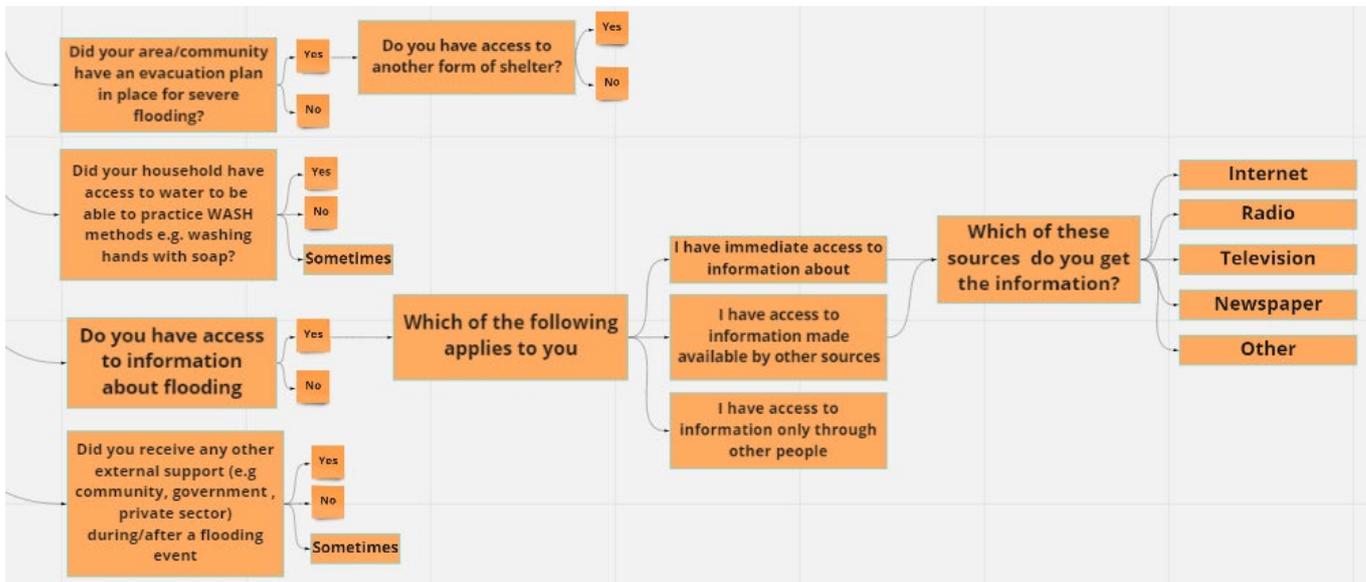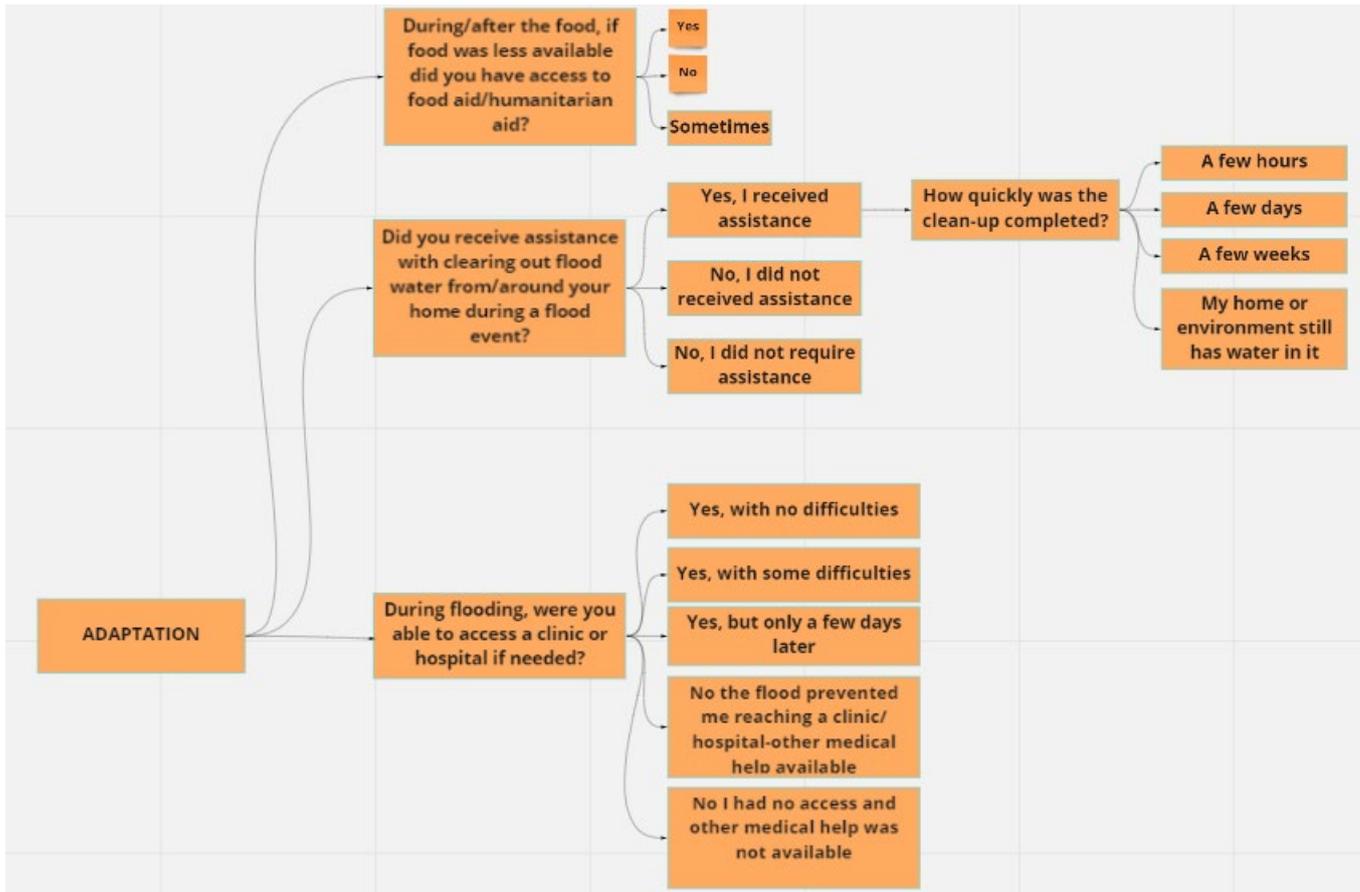**Figure 11: Flood Flow; Sensitivity after**

Figure 12: Flood Flow; Adaptation
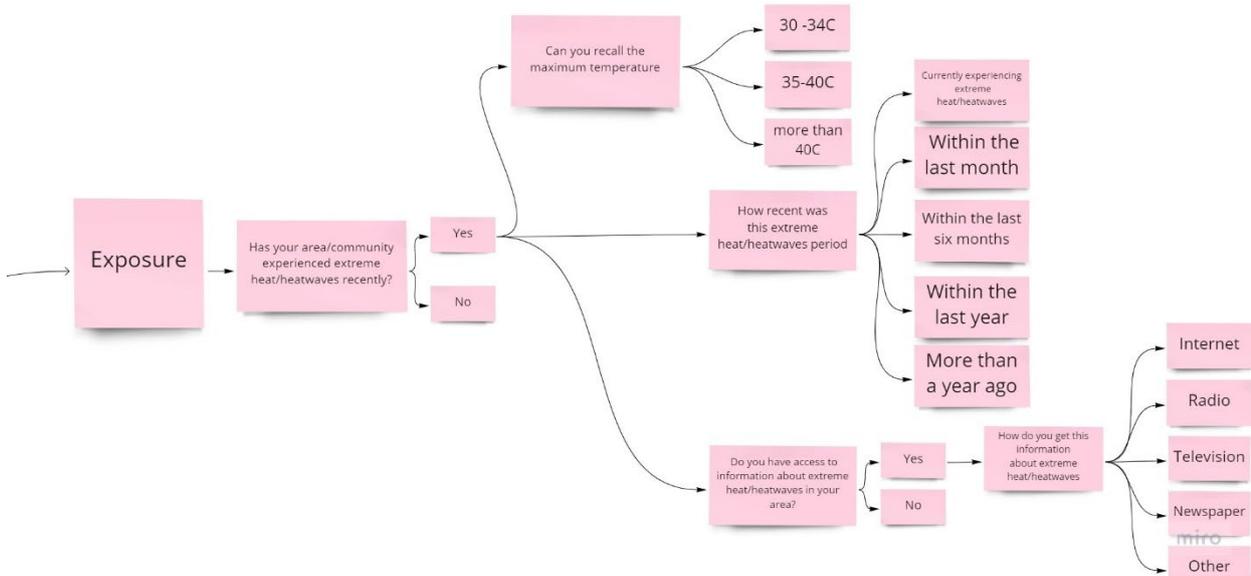
6.3.2 Heat Framework Details

Figure 13: Heat Flow; Exposure

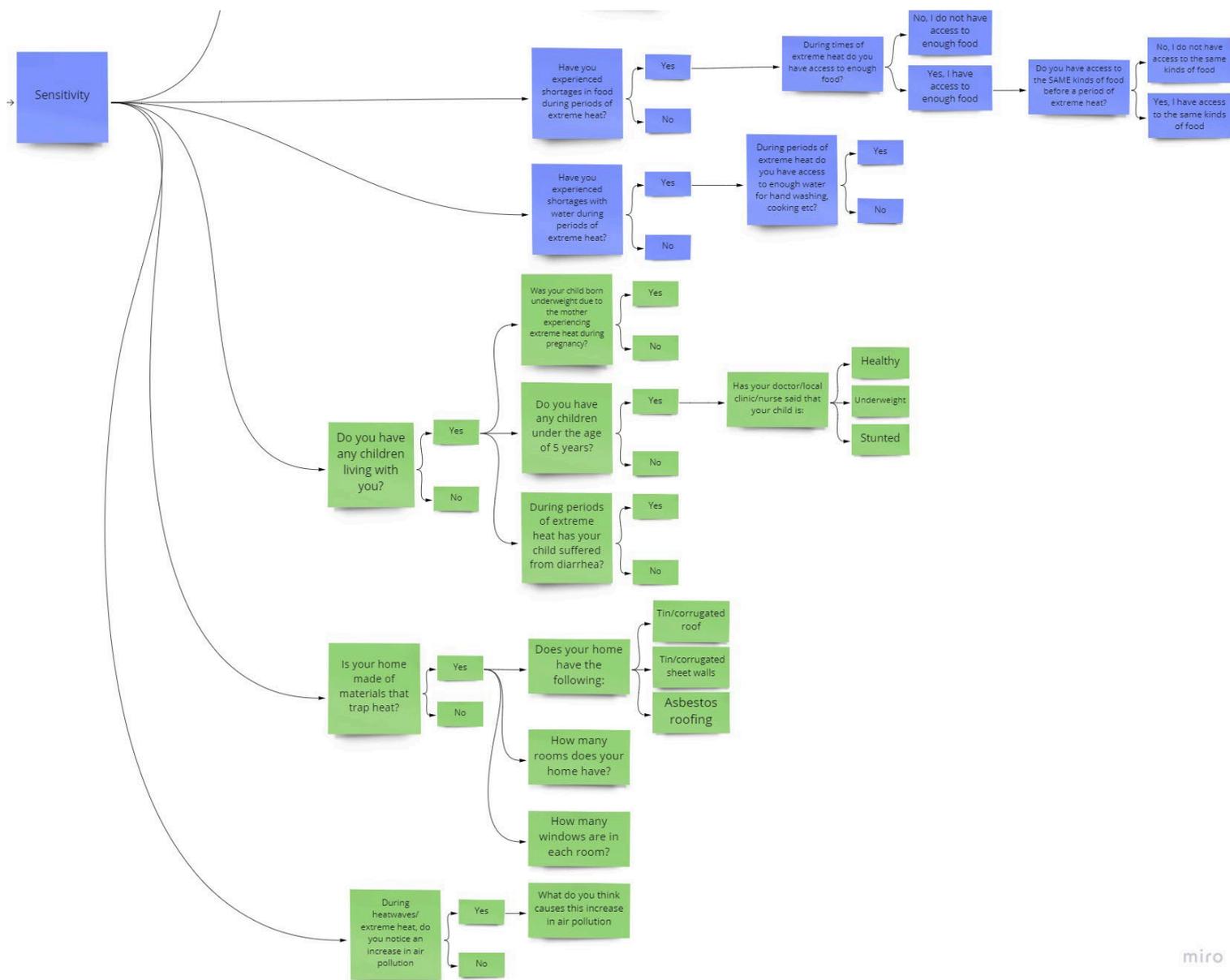**Figure 14: Heat Flow; Sensitivity 1**
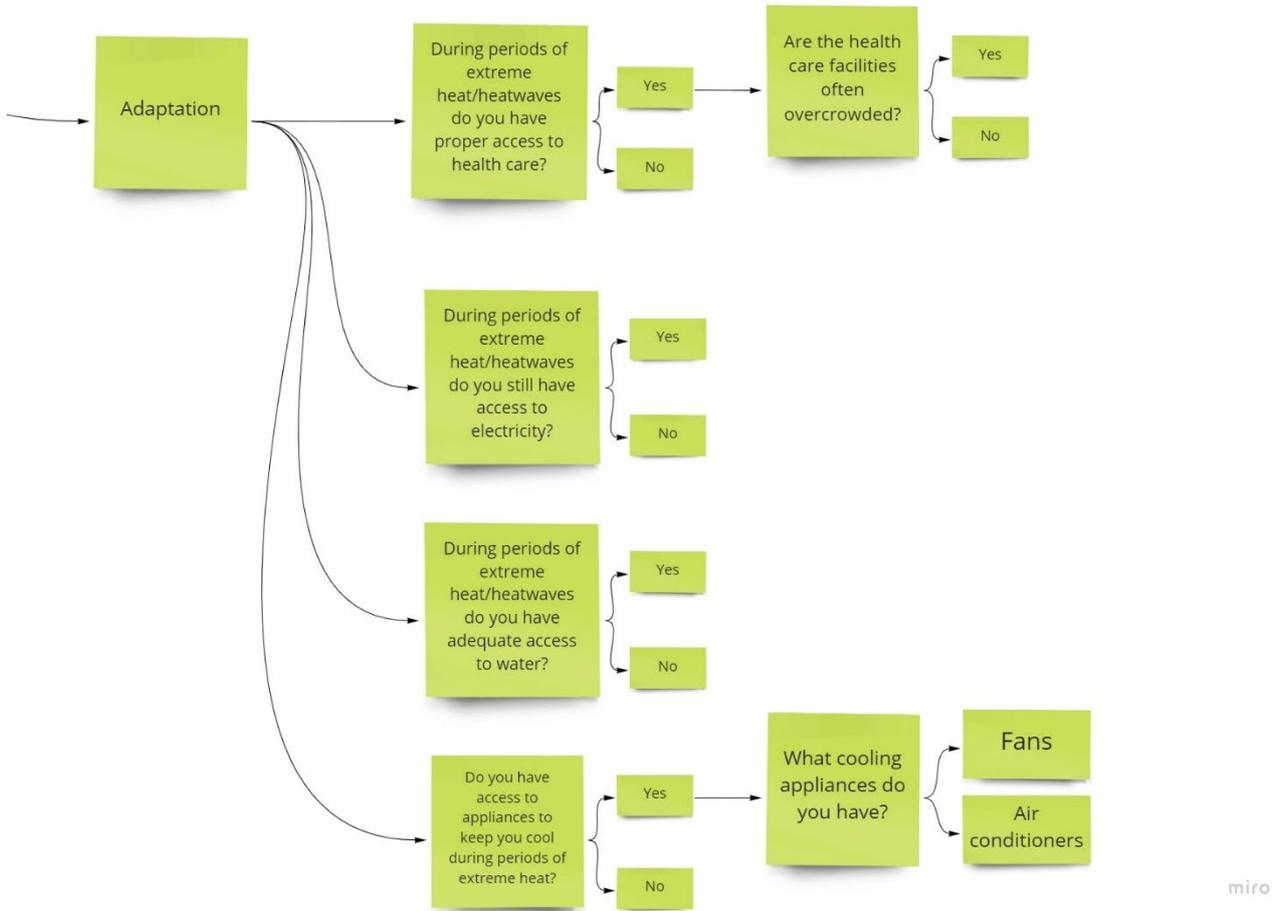
Figure 15: Heat Flow; Sensitivity 2

Figure 16: Heat Flow; Adaptation

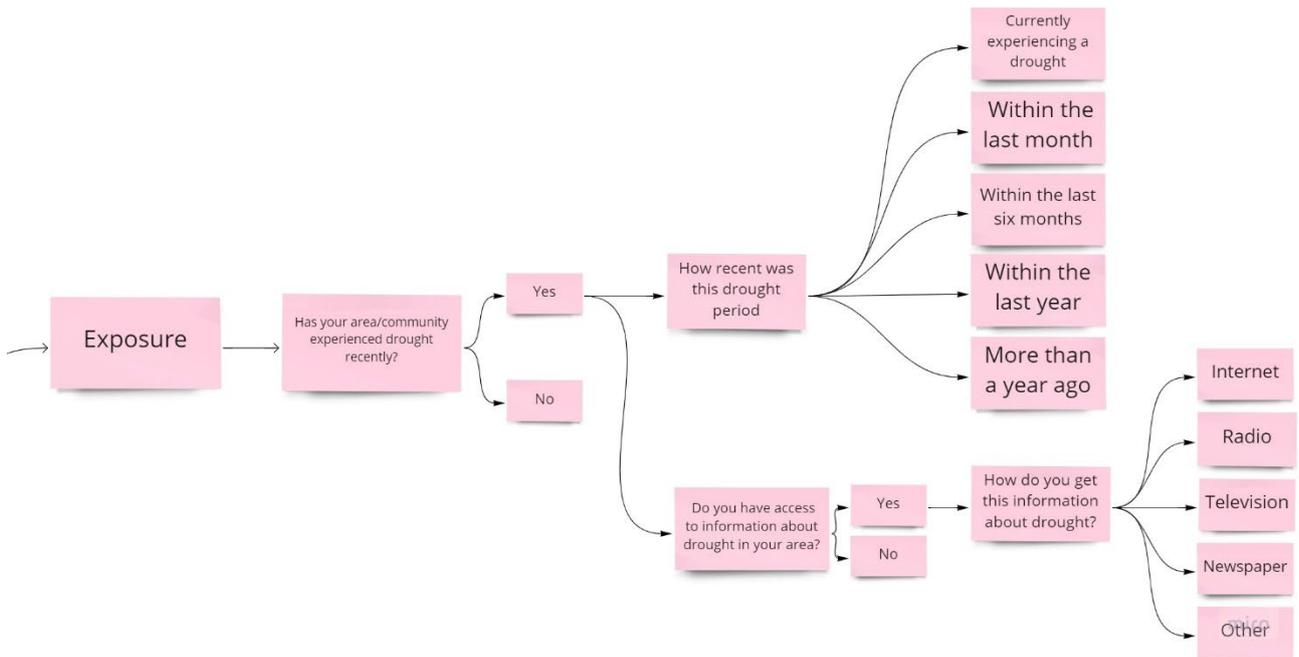### 6.3.3 Drought Framework Details
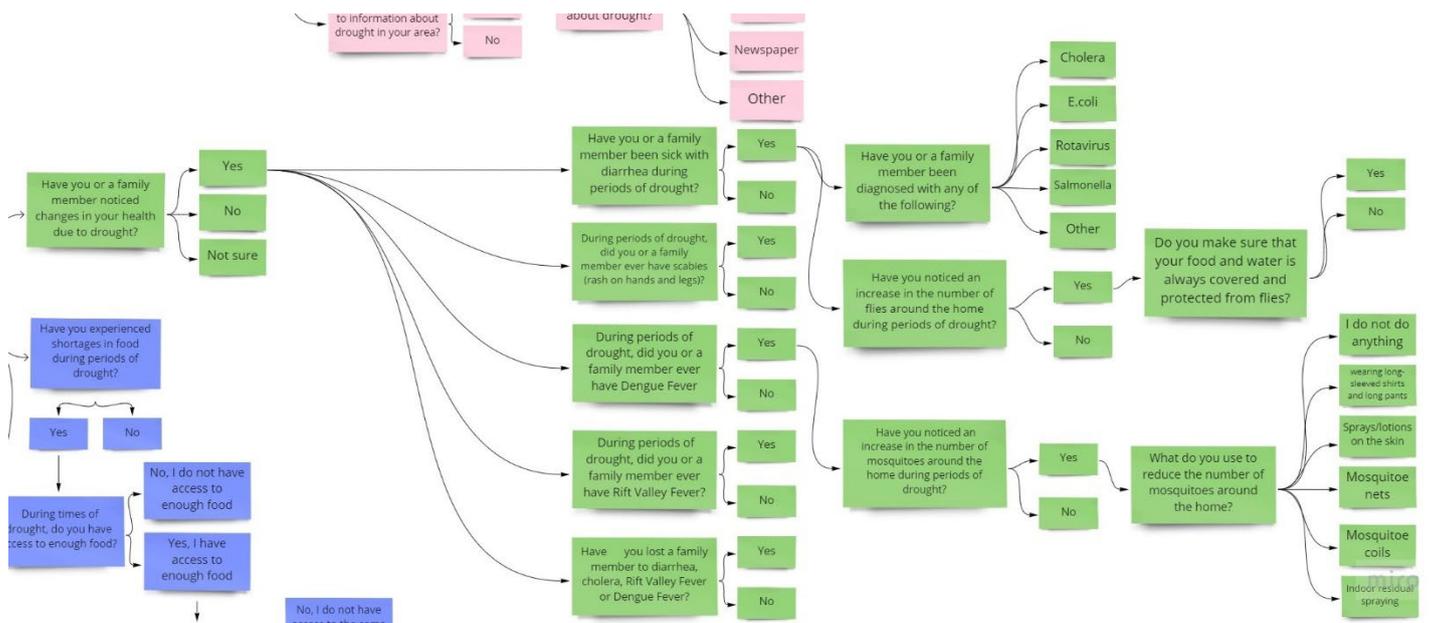

Figure 17: Drought Flow; Exposure

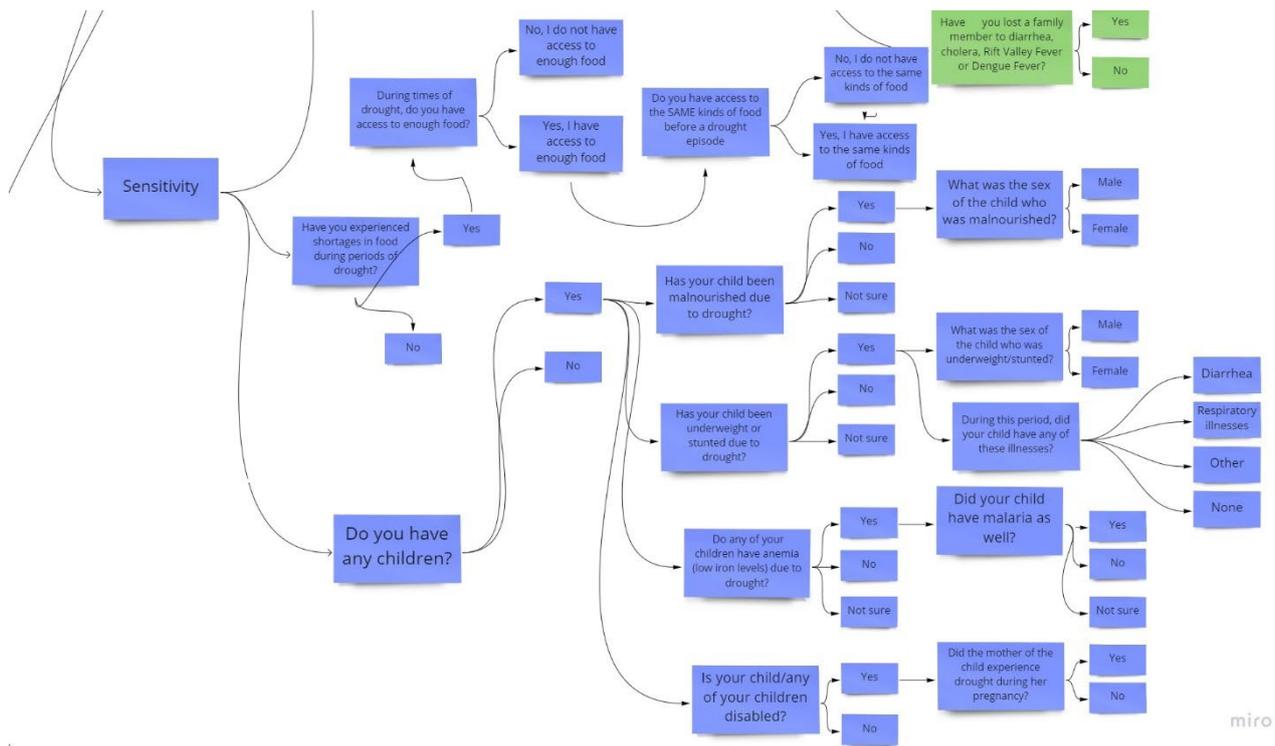**Figure 18: Drought Flow; Sensitivity 1**

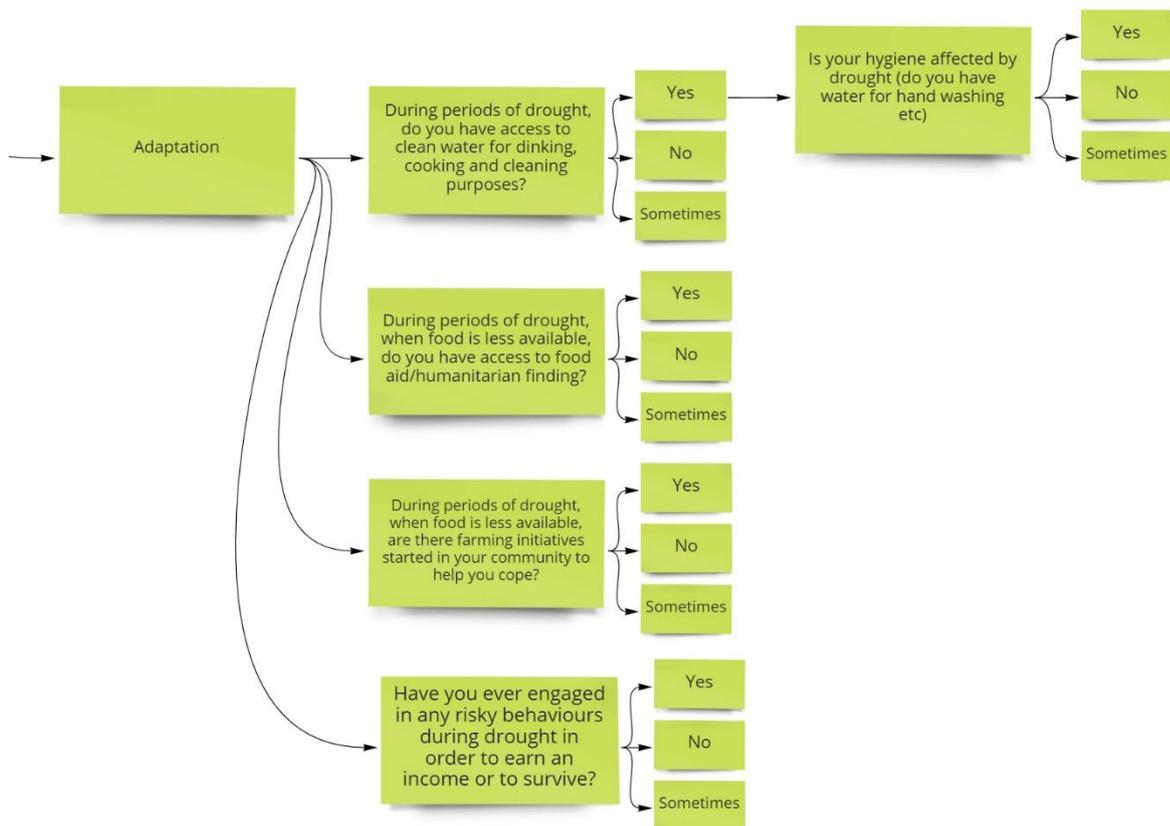**Figure 19: Drought Flow; Exposure 2**

Figure 20: Drought Flow; Adaptation

6.3.4   Score Sheets: One Completed Example

As mentioned in Chapter 4, the score sheets that align with the flow/pathway diagrams, or the larger frameworks we have developed work by adding together exposure, and sensitivity and subtracting from that combined amount the adaptative capacity scores. This process is in line with other similar indicators based approaches (see Cutter et al) when little data is available to validate and cross reference against large data sets. This means, a number of reiterations and workshops are needed to develop an understanding for meaningful ranges in scores to determine types of vulnerability (extremely vulnerable, vulnerable, limited vulnerability, little to no vulnerability). At the moment, for example, from the Flood Vulnerability Indicators below, scores can range from -24 (absolutely no vulnerability and extensive adaptive capacity) to 48 (extreme exposure plus extreme sensitivity and no adaptive capacity). More research is needed to provide clear and concise score ranges and thresholds; this should be done by testing the tool on a range of sites and people with varied experiences. The score sheet below has a score of 6, which indicates some vulnerability, but by looking at the breakdown of the score, we can see that this resident lives in a situation of sometimes intense vulnerability, but has developed mediating adaptive efforts.

Flood Indicator Qs – Tabulation format

#	Exposure Question	Score
1	Has your area/neighbourhood experienced flood recently? Yes (1) No (0)	1
	If No – Skip to other extreme weather event	
2	How recent was the last flood? Current (5) last month (4) past 6 months (3) past 12 months (2) more than a year (1)	2
3	How many floods have occurred in your area in the last year? 0 (0) 1-2 (1) 3-4 (2) 5-6 (3) more than 6 (4)	3
4	Did the flood water enter your home? Yes (1) No (0)	1
	If No skip to 5	
4A	How long did the flood water remain in or around your home? <12hrs (0), 24-48hrs (1), (3-7) days (2), >7 days (3)	2
5	Did your household have to be evacuated due to flooding? Yes (1) No (0)	1
	Exposure score /15	10

#	Sensitivity Question	Score
1	Did you notice a change in your health or the health of anyone in your household during the last flood? Yes (1) No (0)	1
	If No skip to 3	
2	During flood, was anyone in your household injured? Yes (1) No (0)	0
	If No skip to 2B	
2A	Did they have to go to the clinic? Yes (1) No (0)	0
2B	During flooding did anyone in your household drown? Yes (1) No (0)	0
3	During flood, was your livelihood disrupted? No, it was not disrupted at all (0) Yes but I was able to continue with some work (1) Yes, totally disrupted (2)	1
4A	Did you or anyone in your household experience diarrhea? Yes (1) No (0)	1
	If No skip to 4B	
4A1	Did they/you have to go to the clinic? Yes (1) No (0)	1
4B	Did you or anyone in your household develop headaches or start vomiting? Yes (1) No (0)	1
	If No skip to 4C	
4B1	Did they/you have to go to the clinic? Yes (1) No (0)	0
4C	Did you or anyone in your household develop a rash? Yes (1) No (0)	1
	If no skip to 4D	
4C1	Did they/you have to go to the clinic? Yes (1) No (0)	1
4D	Did you or anyone in your household develop a cough? Yes (1) No (0)	1
	If No skip to 4E	
4D1	Did they/you have to go to the clinic? Yes (1) No (0)	1
4E	Were they diagnosed with any of the following? Cholera (1) Typhoid/salmonella (1) E.Coli (1) Malaria (1) Measles (1) schistosomiasis (1) any respiratory infection (1) any skin infection (1) other condition (1)	1
5	Did you or anyone in your household experience anxiety, trouble sleeping or distress due to the impacts of flooding? Yes (1) No (0)	0
	If No skip to 6	
5A	Did they have to receive professional help/counselling? Yes (1) No (0)	
6	After the flood how often were you able to access clean drinking water? All the time (0) occasionally (1) hardly ever (2)	1

6A	What was your source of clean drinking water? My usual water source was unaffected (0) Able to purchase clean water (1) treat own water (by bleach or boil) (2) Clean water was provided by other parties e.g. NGO's (3)	0
7	After the flood, did you have enough food? Yes (0) No (1)	0
	If no, skip to 7A1	
7A	Do you have access to the same kinds of food that you had access to before the flood? Yes (0) No (1)	0
7A1	During flood was your food supply/food stores contaminated? Yes (1) No (0)	1
	Sensitivity score	/33 12

#	Adaptation Question _ SCORES HERE ARE NUMBERED IN SUCH A WAY THAT ADAPTATION TOTAL SHOULD BE SUBTRACTED FROM THE SUMS OF THE OTHER TWO	Score
1	Did you receive assistance with clearing out flood water from your home or close environment? Yes, the flood was severe, and I received assistance (1) No, the flood was severe, and I did not received assistance (0) No, the flood was not severe, and I did not need assistance (0)	1
1A	How quickly was the clean-up completed? A few hours (3) A few days (2) A few weeks (1) My home/environment still has flood water in it (0)	1
2	During flood, were you able to access a clinic or hospital if needed? Yes, with no difficulty (4) Yes, with some difficulty (3) Yes, but only a few days later (2) No, the flood prevented me from reaching care, but other medical help was available (1) No, the flood prevented me from reaching care and there was no other help available (0)	2
3	Does your area/community have an evacuation plan in place for severe flooding? Yes (1) No (0)	1
3A	If you had to leave your home due to flooding, do you have access to another form of shelter? Yes (1) No (0)	1
4	During and right after the flood, if food was less available, did you have access to food aid? Yes (2) Sometimes (1) No (0)	2
5	Did your household have access to water to be able to practise WASH techniques such as washing hands with soap? Yes (2) No (0) Sometimes (1)	2
6	Do you have access to information about flooding in your area? Yes (1) No (0)	1
	If No – Skip to 7	
6A	If Yes, which one applies to you? I have immediate access to information about flooding (2) I have access to information when it is made available by other sources (1) I have access to information only through other people (0)	0
6A1	How do you get this information about flooding? Internet (1) Radio (1) Television (1) Newspaper (1) Other (1)	1
6A2	If Other, please explain _____	
7	Did you receive any other external support (e.g community, government, private sector) during/after a flooding event? Yes (2) No (0) Sometimes (1)	2
	Adaptation score	/24 14

22 - 14 (6)

6.3.5 Consolidated Demographics Questions and General Indicators (household type, etc.)

SECTION A: DEMOGRAPHIC INFORMATION

Concept	Proxy variable
General	**1.Name (Optional) or initials** *LC*
Age	**2. What is your age?** _51_

Sex	**3. What is your sex?**
	  a) Male ✓
	  b) Female

Marital status	**4. What is your marital status?**
	  a. Single
	  b. Married ✓
	  c. Divorced/separated
	  d. Widowed
	  e. Polygamous marriage (married to more than one person)
	  f. Living with partner

Household head	**5. Are you the head of the household?**
	  a. Yes ✓
	  b. No

Household size	**6.1 How many adult Male(s) are in the house?** *3* _3_ **6.2 How many adult Female(s) are in the house?** *2* _2_

Children	**7.1 How many children below the age of 16 are in the household?**
	_2_
	
	7.2 Please indicate the age and sex of each child in the household:
	Child 1: Age _14_ **Sex: (Male or Female)** _Female_
	Child 2: Age _6_ **Sex: (Male or Female)** _Female_
	Child 3: Age _____ **Sex: (Male or Female)** _____
	Child 4: Age _____ **Sex: (Male or Female)** _____
	Child 5: Age _____ **Sex: (Male or Female)** _____
	Child 6: Age _____ **Sex: (Male or Female)** _____
	Child 7: Age _____ **Sex: (Male or Female)** _____
	Child 8: Age _____ **Sex: (Male or Female)** _____
	Child 9: Age _____ **Sex: (Male or Female)** _____
	Child 10: Age _____ **Sex: (Male or Female)** _____
	
	7.3 Do any of the children take vitamin A supplements?
	  a. Yes
	  b. No ✓
	  c. Sometimes
	7.4 If yes, how old are the children taking supplements?
	_____
	
	7.5 Is anyone in the household pregnant?
	
	  a. Yes
	  b. No ✓

Elderly	**8. How many people above the age of 65 live in the household?** _0_

Disability	**9.1 Does anyone in the household have a disability?**
	  a. Yes
	  b. No ✓
	9.2 How many people in the household have a disability?
	_0_

Education	**10. What is your highest level of education?**
	   a. No formal education
	   b. Primary (Grade 1-7), but not completed
	   c. Primary (Grade 1-7) completed
	   d. Secondary (Grade 8-12), but not completed
	   e. Secondary (Grade 8-12), completed
	   f. Tertiary (Post-Grade 12)/diploma/degree ✓

Income	**11.1 What are your source(s) of income (you may select more than one option)**
	   a. Full-time employment ✓
	   b. Part-time employment
	   c. Social government grants
	   d. Pension
	   e. Family or neighbor's support
	   f. Other, (Please specify) Self-projects

Household
Employment
	12.1. How many people in your household are employed in these categories? (Refers to those 15 years old and above)
	   a. Full time____3____
	   b. Part-time_____
	   c. Contract_____
	   d. Unemployed_____
	   e. Pensioners_____
	   f. Self-employed_____
	
	12.2. What is the household's monthly income?
	
	   a. 0 - 5k per month ✓
	
	   b. 6 - 15 k per month
	
	   c. 16 - 25 k per month
	
	   d. 26 - 35 k per month
	
	   e. >35k per month
	
	12.3. How many people are unemployed and depend on the household income (please count children as well)?
	____5____

Social grants	**13.1 How many people are reliant on social grants?** ____0____ **13.2 How many people are reliant on pension?** ____0____

SECTION B: GENERAL INDICATORS

Pre-existing
illnesses
	1. Does anyone in the household have a chronic health condition?
	   a. Yes
	   b. No ✓
	1.2 If yes, how many have a chronic health condition?
	_____
	
	1.3. If yes, are they receiving treatment?
	1.3. If yes, how often do they go to the clinic?
	   a. Once a week
	   b. Once a month
	   c. Once every two months
	   d. Once every three months
	   e. Once every four months
	   f. Once every five months
	   g. Once every six months
	   h. Once a year

Water access	**2.1 What is this household's main source of water?** a. Piped (tap) water in dwelling b. Piped (tap) water on site or in yard c. Public tap d. Water-Carrier/tanker e. Borehole on site ✓ f. Borehole off site/communal g. Rain-water tank on site h. Flowing water/stream i. Dam/pool/stagnant water j. Buying from vendors k. Well l. Spring m. Neighbour n. Other (Please specify) _____ **2.2 How far is the water source from the dwelling?** a. Less than 100 m b. 100 m - less than 200 m c. 200 m - less than 500 m d. 500 m - less than 1 km e. 1 km or more f. water on site (in the home) ✓ g. Don't know
Sanitation	**3.1. What type of toilet facility is available for this household?** a. Flush toilet ✓ b. Chemical toilet c. Pit latrine with ventilation pipe (VIP) d. Pit latrine without ventilation pipe e. Bucket toilet/Portable toilet f. Other (Please specify) e.g, open area_____ **3.2. Is the toilet facility shared with other households?** a) Yes b) No ✓
Energy source	**4. What is your main source of energy?** a. Electricity from mains ✓ b. Electricity from generator c. Solar energy ✓ d. Wood e. Coal f. Paraffin g. Gas h. Animal dung i. Other: _____
Type of residence	**5.Which best describes your community?** a. Urban ✓ b. Peri-urban c. Rural
Housing structure	**6.1. Type of house:** a. Permanent (stone brick) ✓ b. Semi-permanent (e.g. mud wall, iron sheet) c. Thatch roofing with either stone or mud wall

	d. Polythene/wooden shack
	6.2. Roof Type:
	a. Tile or roofing ✓
	b. Tin/corrugated sheets
	c. Asbestos
	d. Thatch
	e. Zinc
	f. Other, please specify_____
Accessible care	**7.1 How far is the clinic/hospital from your home?**
	a. The clinic/hospital is within walking distance for me (less than 5km)
	b. I can travel to the clinic/hospital with my own transport ✓
	c. I can travel to the clinic/hospital using public transport
	d. The clinic/hospital is very far from my home and I have difficulty getting there
	7.2 Are the roads in your area/community in good condition so that emergency services are able to get to you in case of an emergency?
	a. Yes
	b. No ✓
Food	**8.1 In the past four weeks, did you worry that your household would not have enough food?**
	a. Yes
	b. No ✓
	8.2 In the past four weeks, did any household member go all day and night without eating anything because there was not enough food?
	a. Yes
	b. No ✓
	8.3 Do you grow your own crops for the household?
	a. Yes
	b. No ✓
	8.4 If yes, what are the main reasons for growing farm produce for the household? (Please circle the correct option)
	a. As a main source of food for the household
	b. As the main source of income/earning a living
	c. As an extra source of income
	d. As an extra source of food for the household
	e. As a leisure activity or hobby e.g. gardening
	f. Other (please specify):_____
	8.5 Do you keep livestock for the household?
	a. Yes
	b. No ✓
	8.6 If yes, what are the main reasons for keeping the livestock for the household? (Please select the correct option)
	a. As a main source of food for the household
	b. As the main source of income/earning a living
	c. As an extra source of income
	d. As an extra source of food for the household
	e. Other (please specify): _____
Waste disposal and and drainage	**9.1 How do you dispose of solid waste/dirt/garbage?**
	a. Throw anywhere outside the house
	b. Dump very far outside the house
	c. It is regularly collected by a garbage truck
	d. It is infrequently collected by a garbage truck
	e. I pay someone to go dump garbage
	f. a pit dug outside the house ✓ and I burn papers

	g. Burn the garbage
	9.2 What is the state of drainage around the house?
	a. Non-existent (water comes in or flows closely past the house)
	b. There is planned water drainage systems that work
	c. There is planned water drainage systems but filled with garbage
	d. I have dug a tunnel to divert water around the house
Coping with weather shocks	**10.1 Which statement best describes you?** a. My livelihood is impacted entirely by extreme weather events (flooding, drought, extreme heat, wildfires) b. My livelihood is challenged or made difficult by extreme weather events (flooding, drought, extreme heat, wildfires) but I am still able to make a living c. My livelihood is not impacted by extreme weather events (flooding, drought, extreme heat, wildfires) **10.2 How does the household cope with major income shocks (e.g drought, death of a breadwinner, job loss, etc.). Please circle Yes or No** a. Sell livestock (Yes/No) b. Take on additional work (Yes/No) c. Sell other assets (Yes/No) d. Reduce spending (Yes/No) e. Use own cash savings (Yes/No) f. Reduce food consumption (Yes/No) g. Borrow money from relatives (Yes/No) h. Reduce or stop debt repayments (Yes/No) i. Borrow money from stokvel (Yes/No) j. Other, (please specify) _____
Community Cohesion Indicators	**11. Which statement best describes the community you live in? (Please select one)** a. There is no community interaction or support. I am excluded from making decisions regarding my own community. There is no trust between members in the community. b. There is very little community interaction or support. I am sometimes excluded from making decisions regarding my own community. There is not a lot of trust between members in the community. c. There is good community interaction or support. I am always included from making decisions regarding my own community. There is a lot of trust between members in the community.
Conflict or violence	**During periods of extreme weather events (flooding, drought, extreme heat, wildfires), have you noticed changes in the level of violence in your area/community?** a. Yes, there is an increase conflict over access to resources b. Yes, there is an increase in interpersonal conflict (at home or among neighbors) c. No there are no changes in the level of violence

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