



**UNIVERSITY OF CAPE TOWN**  
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

**The adverse health effects associated with drought in  
Africa: Working towards developing a vulnerability index**

**Taherah Asmall**

**Master's in Public Health (Environmental Health)**

**School of Public Health and Family Medicine**

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# **Part 0: Preamble**

**Candidate:** Taherah Asmall (ASMTAH001)

**Supervisor:** Professor Mohamed Aqiel Dalvie

Director of the Centre for Environment and Occupational Health

Research

School of Public Health and Family Medicine

UCT Faculty of Health Sciences

**Co-supervisor:** Dr Amber Abrams

Postdoctoral Fellow at Future Water

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## Declaration:

I, Taherah Asmall, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, or is to be submitted for another degree in this or any other university.

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## **Abstract:**

Africa is uniquely vulnerable to the occurrence of drought. A rise in temperatures over Southern Africa occurs at almost twice that of the global rate. South Africa has begun to experience an increase in the frequency of drought, particularly in the Western and Eastern Cape. Droughts are associated with several health effects. The direct and indirect risks of climate change to human health have become a global concern. The most recent systematic review available on the adverse health effects associated with drought was published in 2013, and as such, an up-to-date review focusing on Africa is needed to inform a Cape Town specific health vulnerability index.

This study aims to provide a review of available research exploring the association between drought and adverse health effects in Africa. The rationale for this study is to provide a solid research foundation from which a drought-specific health vulnerability index for Cape Town can be developed. A narrative review of original studies and published reviews was conducted. An extensive electronic literature search was performed using a combination of keywords, Medical Subject Heading (MeSH) terms and free text words. The Critical Appraisal Toolkit (CAT) was used to assess the quality of included studies.

A total of 1922 publications were identified, of which twenty-four articles were included in this review. The main drought-related health effects that emerged were divided into 4 main categories: (1) drought and nutritional health including malnutrition, poor childhood health outcomes (wasting, stunting and underweight), mortality, anaemia, and nutrition-related disability; (2) drought and food consumption including micronutrient deficiencies and motor neuron diseases; (3) drought and water-borne, water-washed and water-

related diseases including cholera outbreaks, diarrhoeal diseases, protozoa parasite transmission, scabies outbreaks, trachoma, vector-borne disease outbreaks and malaria-related mortality; and (4) drought and health behaviours including health perceptions and health-seeking behaviours, HIV prevention and care behaviours and family planning practices. There was generally limited evidence in all health categories with several limitations. These limitations include studies with methodological weaknesses (e.g. a lack of comparison to a non-drought period), the singularity of published studies on health effects associated with drought and studies which did not account for potential confounders.

While the evidence from the included studies is limited, this study highlights gaps in literature to encourage further research into understanding the direct and indirect impacts of drought on health, particularly in vulnerable groups. Furthermore, the results of this study emphasized the contextual factors which lower an individual's adaptive capacity and identified key indicators that can be used to begin to develop a broad framework for a vulnerability index.

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#### Keywords:

Droughts, Africa, Climate, Nutrition, Water-borne, Behaviour, Vulnerable groups

#### Highlights

- First review of studies on health effects of droughts in Africa
- Existing evidence in Africa on adverse health outcomes and drought is limited
- Vulnerable groups identified
- Research gaps for future studies identified



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# **Part A: Protocol**

## 1. Introduction

### 1.1 The impact of climate change on health

Industrialization has created a greater demand for energy, largely sourced by burning fossil fuels, subsequently resulting in increased carbon dioxide and other greenhouse gas emissions into the atmosphere (Mirsaeidi et al, 2016). The upsurge in these emissions from predominantly anthropogenic sources has caused unparalleled changes to climate (Patz et.al, 2014). A rise in temperature from trapped heat within the atmosphere alters rainfall patterns and increases extreme weather events, varying across geographical regions (Walker, 2018). Accumulated empirical evidence has identified direct and indirect risks of climate change to human health as a global concern (Kjellstorm and McMichael, 2013).

Extremes in weather including droughts, heatwaves, flooding, severe storms and rising sea levels are amongst direct mechanisms that have the potential to adversely affect health. Indirect mechanisms, such as the increase in air pollution and the incidence of infectious diseases, threaten the health of populations as well (Patz et.al, 2014). Climate change effects could similarly exacerbate pre-existing health conditions (Kjellstorm and McMichael, 2013).

Presently, one-third of the world's population resides in areas that are water-stressed for at least one month in the year (Mekonnen and Hoekstra, 2016). As a consequence of high temperatures, increased soil moisture evaporation and a lack of precipitation events, severe drought arises (Patz et.al, 2014). Reduced access to clean drinking water, in the case of severe drought, could lead to water-washed and water-related diseases such as diarrhoea. Storage of water creates a favourable environment for microorganism growth and bioaccumulation (Walker, 2018). Furthermore, a decrease

in agricultural production owing to the effects of drought could lead to under-nutrition, malnutrition, developmental delays in children and mental health issues (Kjellstorm and McMichael, 2013). Mental health is a domain of individual well-being that simply cannot be overlooked, and evidence suggests an increase in the rate of suicide amongst farmers during periods of severe drought (Hanigan et.al, 2018). The effects of drought on human health are therefore widespread and will vary significantly depending on contextual factors (Stanke et.al, 2013).

## **1.2 Drought in Africa**

This review focuses on the adverse health effects of drought, particularly studies done in Africa. Studies conducted in this region/continent are of significance due to a substantial increase in the occurrence and impact of drought episodes since the 1980s (Kamara et.al, 2018). A total of 291 episodes of drought have been reported in Africa between 1900-2013, resulting in 847 143 deaths (Masih et al, 2014). The African continent is an enormous mass of land, with geographically diverse landscapes and subsequently, the effects of climate change vary widely depending on location (Collier et al, 2008). Some regions experience drought once every two years, but in the past 12 years, the horn of Africa has been affected by drought every year, with Kenya experiencing severe droughts in 2009 and 2012 (FAO, n.d). Within East Africa, during 2000-2014, Burundi, Ethiopia, Mozambique and Somalia each experienced 5 different episodes of drought (Masih et al, 2014). These recurrent episodes place a unique strain on populations in Africa which have a high dependence on agricultural activities (Collier et al, 2008).

For example, food production in Africa is adversely affected, with a decrease in wheat production in the north and maize production in the south (Collier et.al, 2008). Africa

has the highest prevalence of undernourishment of approximately 20% (FAO, 2019). The association between drought and malnutrition, compounded by the inability to import food into certain regions, places countries in Africa at a disadvantage to adapt to the effects of drought (Patz and Kovats, 2002).

Africa is also uniquely vulnerable to rising temperatures in Southern Africa which is occurring at an alarming rate- almost twice that of the global rate (Engelbrecht et.al, 2015). Furthermore, Southern Africa is particularly susceptible to an increase in the risk of drought due to the occurrence of the El-Niño phenomenon, which is unusual warming of surface water in the Pacific (Collier et.al, 2008). Thirty-two known episodes of drought have been reported in Southern Africa during 1900-2014, with South Africa experiencing 8 drought episodes during 1964-2004 (Masih et al, 2014).

In South Africa, the most notable consequence of the rise in temperature is the occurrence of episodes of drought, particularly in the Western Cape and the Eastern Cape (Chersich et.al, 2018, Department of water and sanitation, 2018). In the past, the city of Cape Town, located in the Western Cape, experienced an ample supply of water. The 2013 and 2014 annual rainfalls exceeded the normal amount, resulting in reservoirs being filled. However, during 2015-2017, water availability became critically low, with reserves containing only 38% (Ziervogel, 2019, Muller, 2018). Resilience to the impacts of drought in Southern Africa is greatly inadequate and not as prioritized as it should be (Holloway, 2003). Health care systems in Sub-Saharan Africa are weak, under-resourced and slow to respond to health crises. This is due, in part, to the large imbalance between disease burden and the number of skilled healthcare workers employed (Kirigiaand and Barry, 2008). Anyangwe and Mtonga (2007) reported that in

2006 this region, compared to the rest of the world, experienced a high disease burden (24% of the global burden of disease), while employing approximately 3% of the global health care labor force. Another possible reason for this unfortunate situation could be the existing underlying political, social and economic vulnerabilities (Kamara et.al, 2018). The complexity of these existing vulnerabilities that many Southern African countries face, substantially weakens resilience in response to natural disasters such as drought. In countries that have a high HIV/AIDS burden, for example, a large percentage of the population is immunocompromised, and a drought situation could lead to an increase in the incidence of infections (Holloway, 2003).

### **1.3. Health Vulnerability Index**

In 2003 the Epidemiology and Information Office of the health department of Belo Horizonte developed the Health Vulnerability Index (HVI) aimed at evidencing the socioeconomic inequalities between different groups in a society. HVI is a synthetic indicator that weighs up socioeconomic factors as follows; housing (10%), income (20%), sanitation (20%), education (20%) and other social aspects that impact health (30%) (Pastrana et al, 2014). These factors also referred to as social determinants, impact profoundly on the health status of individuals (Mohapatra, 2012). HVI has been used in various settings as a tool to explore links between social health risks and disease distribution (Pastrana et al, 2014). The purpose of such explorations is to prioritize public health resources to improve the health of vulnerable individuals or communities (Rappold, 2017).

The definition of vulnerability has evolved and expanded over time to a multidimensional concept, having different discipline-specific denotations. The Third Assessment Report of the IPCC defines vulnerability as a system's susceptibility or the inability of a system to cope with the adverse effects, variability and extremes, as



experienced in the current context of climate change (Mohapatra, 2012). There are three interrelated dimensions affecting vulnerability: exposure to risk, social factors which makes people vulnerable to extreme climate events and the adaptive capacity of individuals or communities (Schumann and Moura, 2015). The extent of vulnerability to climate extremes such as drought varies substantially over time and is geographically dependent (Cutter et al, 2003). Age, gender, access to resources and characteristics of communities directly influence the degree of vulnerability (Iqbal et al, 2015).

A conceptual model highlighting the interactions between environmental disasters (such as drought), socio-demographic factors and health effects can be useful for vulnerability assessments (Confalonieri et al, 2014). In Figure 1 below, Confalonieri et al, (2014) explicate that climate change is expected to change water cycles thereby reducing water availability impacting hygiene practices, food production and migration. Consequently, there is an expected increase in infectious diseases which increases demand for health care facilities. During periods of prolonged drought, an increase in migration could occur and could affect the redistribution of prevalent infectious diseases.

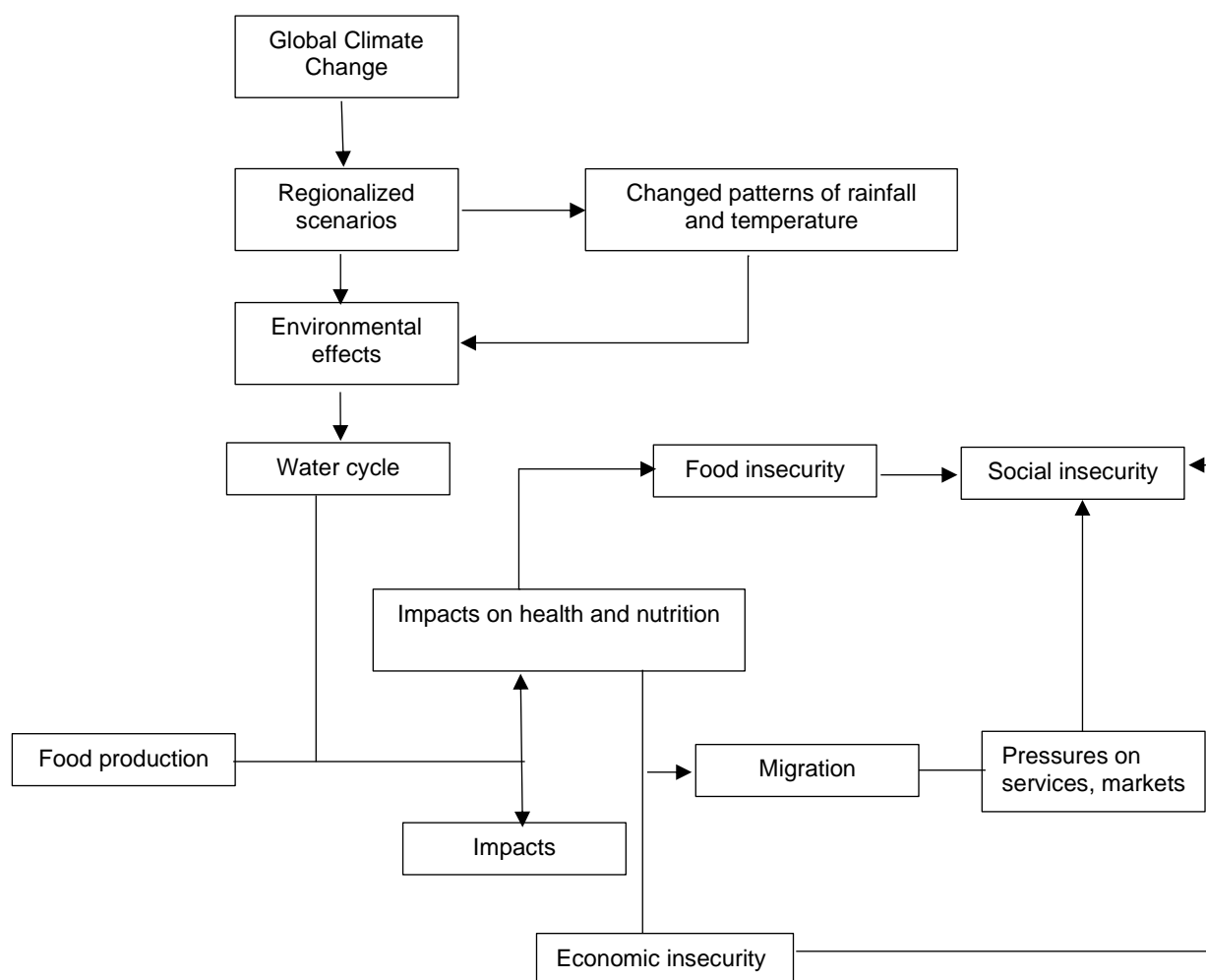


Figure 1: Conceptual model on climate change, migration and health (Confalonieri et al, 2014)

Assessing population vulnerability allows for the identification of those who are at greatest risk of exposure to environmental hazards. As mentioned previously, a populations' vulnerability to the effects of climate change is dependent on several factors including geographic location, low adaptive capacity and regional sensitivity to climate-related diseases (Patz et.al, 2014). Vulnerability assessments are essential for government entities to identify those most susceptible to the adverse effects of climate change and for resources to be allocated equitably (Manangan, 2016). Long-term

strategies need to be implemented to deal with climate change variability and subsequent effects (Muller, 2018).

In 2018, the South African Water Research Commission (WRC) circulated a Call for Proposals (CFP) for the development of a Cape Town specific HVI. Although the funding application was successful, contractual issues between the University of Cape Town and WRC meant that the project funding never materialized, however, my project was already in progress. This evidence-based review was undertaken to assist in developing an HVI for drought for the city of Cape Town, South Africa, by exploring the health effects of drought.

## **2. Aims and objectives:**

### **2.1 Aims**

This study aims to provide a review of available research, published between 2012 to 2019, exploring the association between drought and adverse health effects in Africa.

### **2.2 Objectives**

The objectives of this study are as follows:

- To systematically search, identify and extract literature regarding the direct and indirect adverse health effects due to drought.
- To comprehensively identify the type(s) of health effects associated with drought 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 drought-specific health vulnerability index for Cape Town.

### **2.3 Study justification**

Episodes of extreme weather events, such as drought, have increased and become a significant public health concern globally (Hanigan et.al, 2018). In a recent annual report by the World Economic Forum, water scarcity has been listed as the largest global risk with regards to the potential impact, ranging from socio-economic to health consequences (Mekonnen and Hoekstra, 2016). Drought poses a risk to the physical and mental well-being of individuals and communities (Hanigan et.al, 2018). A common example is an increase in pathogen exposure from rainwater collection in tanks during periods of drought, which often results in a higher incidence of diarrhoeal diseases (Walker, 2018).

Baseline population vulnerability is one of the key factors underlying the volatile pattern in drought-related health outcomes (Stanke et.al, 2013). The rationale for this study is to provide a solid research foundation from which a drought-specific health vulnerability index for Cape Town can be developed. The most recent systematic review available on the adverse health effects associated with drought was published in 2013 (Stanke et, al.2013) and as such, an up-to-date review focusing on Africa, in particular, is needed to inform a Cape Town specific health vulnerability index. The goal is for the index to be used to inform policy, resource allocation and interventions related to adverse health outcomes associated with drought.

### **3. Methods**

#### **3.1 Search strategy**

An extensive electronic literature search will be conducted using the following databases:

- Pubmed (Medline platform)
- Scopus (includes Medline, Embase and citation index)
- Web of Science (includes citation index)
- Africa-Wide (includes articles focusing on the African context)

Narrative summaries and overviews of qualitative evidence exploring the association between drought and adverse health effects will be conducted from peer-reviewed articles. A combination of keywords, Medical Subject Heading (MeSH) terms and free text words will be used to search for articles (Appendix A1). Articles will also be extracted from the reference list and citation indexes of all found articles. Grey literature, which is research that is unpublished or published in a non-commercial form (such as fact sheets), will also be searched using Google Scholar and other databases (Appendix A2).

#### **3.2 Data Collection and Analysis**

##### **3.2.1 Study selection**

The Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines (Moher et.al, 2009) will be used for this review (Appendix B).

The titles and abstracts of articles will be used as the first phase of screening, wherein the primary investigator will assess whether they meet the criteria for inclusion or reason(s) for exclusion. Full texts will be read if it is not clear if the article is eligible.

Articles that are excluded will be documented in a table (Appendix C). Duplicate articles will be removed.

### **3.2.2 Data extraction and management**

Summary tables, found in Appendix D, will be used for the extraction of data. Table headings will include; author name(s), article title, year of publication, study design, study specifics (location and methodology), drought exposure, health outcome(s) investigated, results and relevance of the study to HVI. Due to the parameters of the inclusion criteria, it is not likely that quantitative meta-analysis will be conducted due to the heterogeneity of the studies used. However, quantitative results from individual studies will be summarised (Appendix E).

### **3.2.3 Assessment of risks and bias**

Experimental studies on drought are not plausible, therefore studies included would be predominantly observational in nature. The quality of studies will be assessed using the Critical Appraisal Toolkit (CAT), which was developed for the consistent appraisal and grading of scientific evidence (Moralejo et.al, 2017). Studies with obvious weaknesses will be excluded following consultation with supervisors (AD and AA), as needed.

### **3.2.4. Dealing with missing data**

In cases where full-text articles are missing, authors will be contacted if possible.

## **3.3 Inclusion criteria**

A study will be considered eligible if it complies with the inclusion criteria listed below:

- Studies published from 2012 until September 2019 (most recent systematic review on the adverse health effects associated with drought was published in 2013)

- Studies published in English
- Studies which deal with the association between drought and adverse health effects in humans
- Studies in which health outcomes are clearly linked to drought
- Studies with comparative and non-comparative study designs
- Observation studies
- Studies performed in any region and any subgroup in Africa
- Participants of all ages and genders

### **3.4 Exclusion criteria**

A study will not be considered eligible if it meets any of the exclusion criteria listed below:

- Studies published in a language other than English
- Studies which address the effects of drought on other species such as microorganism growth without being linked to an adverse human health effect
- Studies in which the term “drought” is unrelated to climatic conditions

## **4. Ethics**

Although formal ethical approval will not be necessary as this is a desktop review of published information and the research will not involve human or animal subjects, the protocol will be submitted for review to the Faculty of Health Science Human Research Ethics Review Committee at the University of Cape Town to ensure the validity of the study (Appendix F). The results of the study will be made available online and will be submitted to an accredited peer-reviewed journal.

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# **Part B: Article**

*Article to be submitted to the Science of The Total Environment journal and is written in accordance with the instructions for authors (Appendix G).*

## 1. INTRODUCTION

### 1.1 Background

Currently, a third of the world's population resides in water-stressed regions (Mekonnen and Hoekstra, 2016). This situation could be attributed to a rise in temperatures and a decrease in precipitation events, with more frequent episodes of drought, resulting from the increase in carbon dioxide and greenhouse gas emissions from climate change (Patz et.al, 2014). Ardalana et al (2019) suggest that drought causes a multitude of adverse health effects including an increase in diarrhoeal diseases due to reduced or poor hygiene when water is scarce, in addition, malnutrition can occur due to decreased agricultural production; and there may be an increase in vector-borne diseases. The vulnerability of Sub-Saharan Africa (SSA) to climatic disasters, such as drought and floods, has been well-established (Kamara et.al, 2018). South Africa, as part of SSA, has experienced an increase in climate-induced health effects, disproportionately impacting vulnerable groups (Chersich et.al, 2018). A study conducted in Cape Town, on children younger than 5 years, found that a 5 °C increase in minimum weekly temperatures resulted in a 15% increase in the incidence of diarrhoeal cases (Musengimana et.al, 2016). Another South African study, using temperature and mortality data collected over a period of 17 years, found that the relative risk of mortality associated with very cold and very hot temperatures was 1.14 (1.10,1.17) and 1.06 (1.03,1.09), respectively, with children and the elderly being more vulnerable to temperature extremes (Scovronick, et al, 2018).

Climate change vulnerability depends on the community's risk of exposure and social disparities which have been shown to increase susceptibility to extreme climate events and the ability of communities or individuals to cope with adverse effects of climate events (Schumann and Moura, 2015). Africa is considered the most vulnerable

continent to climate change due to the region's high exposure to climate extremes and low adaptive capacity (Awojobi and Tetteh, 2017). It is imperative to assess the evidence on adverse health effects that are associated with climate extremes, such as drought, to identify those who are most at risk to ensure targeted interventions are in place (Holloway, 2010). In Africa, data and research gaps hinder adaptive capacity, increasing the vulnerability of populations (Niang et.al, 2014). The most recent synthesis of the evidence of the health effects associated with drought was published by Stanke et al (2013) on data available through 2012 and was not region-specific.

This study aimed to provide an updated review of available research, published between 2012-2019, exploring the association between drought and adverse health effects in Africa. In southern Africa, rising temperatures are occurring at an alarming rate- almost twice that of the global rate (Engelbrecht et.al, 2015), and where there is a substantial increase in the occurrence of droughts since the 1980s (Kamara et.al, 2018). The objective of the study was to systematically review evidence of the direct and indirect adverse health effects due to drought, to identify those associated with drought and vulnerable groups in Africa. Furthermore, in light of the rise in the occurrence of drought episodes in South Africa, the present study aims to contribute to the development of a drought-specific health vulnerability index for the city of Cape Town, South Africa.

## **2. METHODS**

### **2.1 Study Design**

A narrative review of published, peer-reviewed and unpublished studies and reviews was conducted to determine the adverse health effects associated with drought in Africa.

### **2.2 Literature Search Strategy**

An extensive electronic search was conducted using PubMed, Scopus, Web of Science and Africa Wide. The search strategy included keywords related to Drought AND Health AND African countries. Grey literature was searched using Proquest, Open Grey, Open Doar, Paper First, Proceeding First and Google Scholar. To build on the existing systematic review by Stanke et al (2013), which synthesized evidence published in any year until 2012, the search for this paper was limited to articles published between 2012-2019, and those written in English. See Appendix A.1 and Appendix A.2 for detailed search terms for each database. Additionally, the reference list of included studies was searched.

### **2.3 Selection of reviews**

The Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines were used for this review (Appendix B). A pre-defined set of inclusion and exclusion criteria was established prior to conducting the study to assess which studies would be included in the review. The articles were reviewed by the principal investigator. In cases of uncertainty for inclusion, another reviewer was consulted, and a consensus was reached following detailed discussion.

A study was considered eligible if it complied with the inclusion criteria listed below:



- Studies published from 2012 until September 2019
- Studies published in English
- Studies which deal with the association between drought and adverse health effects in humans
- Studies in which health outcomes are clearly linked to drought
- Studies with comparative and non-comparative study designs
- Observation studies
- Studies performed in any region and any subgroup in Africa
- Participants of all ages and genders

Studies that did not meet the above-mentioned requirements were excluded from the review. Additional exclusion criteria were applied and are listed below:

- Studies published in a language other than English
- Studies which address the effects of drought on other species such as microorganism growth without being linked to any adverse human health effects
- Studies in which the term “drought” is unrelated to climatic conditions

Additionally, the quality of studies was assessed using the Critical Appraisal Toolkit (CAT). This validated tool was chosen due to its wide applicability to analytical, descriptive and review studies. The CAT assessment criteria allowed for comprehensive appraisal of the research (Moralejo et.al, 2017).

### **3. RESULTS:**

A total of 1922 titles and abstracts from electronic and grey literature databases were obtained. No additional references from reference lists of articles, meeting the inclusion criteria, were found. Thirty-two article abstracts met the inclusion criteria. Following the full-text review, 8 articles were excluded. A total of 24 articles, which met the inclusion

criteria, were relevant and therefore included in this study (See figure 1 and Appendix B).

The 24 included articles were further divided into 4 categories: drought and nutritional health (10 articles), drought and food consumption (2 articles), drought and water-borne, water-washed and water related diseases (9 articles) and drought and health behaviours (3 articles).

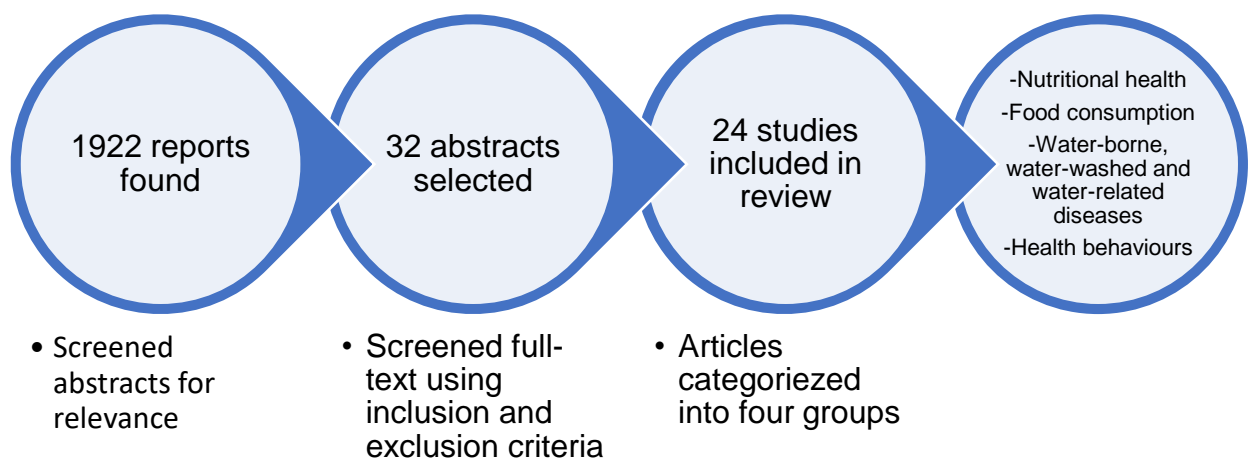


Figure 1: Steps followed in the literature search

### 3.1. Drought and nutritional health:

The increase in natural disasters, such as flooding and drought, creates nutritional crises and leads to an increase in conditions such as malnutrition (Bahwere, 2014). Ten studies (Table 1) explored the effects of drought on nutritional outcomes including (a) malnutrition (n=3); (b) wasting, stunting and underweight (n=4); (c) mortality (n=1), (d) anaemia (n=1) and (e) nutrition-related disability (n=1). From these articles that were reviewed, the evidence of an association between drought and nutritional health was weak. However, other articles may exist for Africa that provide different findings, and which may have been excluded due to the study inclusion criteria (i.e. only studies published in English were included).

Table 1: Studies exploring the adverse effects of drought on nutritional health:

Author name(s) and Year of publication:	Study population and design:	Methods:	Findings:
<b>Malnutrition:</b>			
<b>Bauer and Mburu 2017</b>	An ecological study investigating the effects of drought on child health from 2009 to 2013, in 924 households in the Marsabit District, Northern Kenya	Household and child health information was taken from Index-based Livestock Insurance (IBLI) data. A vegetation index was developed. Surveys were conducted during the dry-season and included a malnutrition index based on mid-upper arm circumference (MUAC)-score.	The prevalence of malnutrition based on MUAC was 20%. A positive association between the vegetation index and MUAC was found especially in boys and older children.
<b>Belay et.al 2019</b>	A cross-sectional study on 422 participants, from 2016 to 2018, to estimate household drought-driven food insecurity in Afar, Ethiopia.	Data to assess food insecurity caused by drought and undernutrition in two randomly selected districts. Randomly selected dwellers, government officials and other stakeholders were included. Malnutrition in children (0-59 months) was assessed using height, weight and mid-upper arm circumference (MUAC). Questionnaires included the Household Food Insecurity Access Scale (HFIAS).	41.9% of respondents relied on food aid or worked for food. In children under five years, 56.8% were <60% for their weight/age, suggesting a high prevalence of malnutrition. Participants reported climate change as the most common cause of food insecurity.
<b>Lazzaroni and Wagner 2016</b>	A cross-sectional study to assess the effects of multiple shocks on the child health outcomes in 2009 and 2011 on 3810 children in Senegal (8 regions).	Surveys on child health and demographics were administered to randomly selected households. A baseline survey was conducted in 2009 (May-June) and a follow-up survey in 2011 (April-May), after an international peak in food prices. Child nutritional status assessed using anthropometric measurements. The climatic shock was based on participant feedback.	In 2009 and 2011, 3% and 6% of households, respectively, reported the occurrence of drought. Authors attribute this low percentage result to surveys being conducted during the dry season. The results in 2009, suggest that the children in that sample were moderately underweight and stunted.

## Wasting, underweight and stunting:

<p><b>Kinyoki et.al 2016</b></p>	<p>A cross-sectional study assessed wasting and stunting amongst 73 778 children aged 6-59 months in Somalia, from 2007 to 2010.</p>	<p>Children were randomly selected for biannual nutritional assessment surveys. Data on environmental variables include rainfall, temperature, distance from water and Enhanced Vegetation Index (EVI).</p>	<p>In children, 21% were wasted, 31% were stunted and 58% were underweight, with boys at higher risk. In a multivariate analysis of EVI, the odds ratio (OR) for wasting was 0.66 (95% CrI: 0.45, 0.95), stunting 0.59 (95% CrI: 0.42, 0.82) and underweight 0.69 (95% CrI: 0.67, 0.72).</p>
<p><b>Kinyoki et.al 2017</b></p>	<p>A cross-sectional study from 2007 to 2010 to investigate the effects of conflict in Somalia on child undernutrition. The sample consisted of 73 778 children.</p>	<p>Study variables were the same as a previous study conducted by Kinyoki et.al (2016). An additional variable on conflict data (violent and non-violent crimes) was collected using Armed Conflict Location and Event Data (ACLED).</p>	<p>An association was found between conflict and undernutrition e.g. in cases of long-term conflict, the OR for wasting was 1.76 (95% CrI (1.71, 1.81), and the OR for stunting was 1.88 (95% CrI (1.83, 1.94).</p>
<p><b>Belayneh et.al 2019</b></p>	<p>A cohort study in Ethiopia, on 894 households, to investigate food insecurity, wasting and stunting in children living in a drought-prone area</p>	<p>The study was conducted in the Boricha area which experienced chronic food insecurity. Data was collected in 2017: pre-harvest (March-June) and post-harvest (September-December). Nine hundred and thirty-five mother-child pairs were studied.</p>	<p>82% (95% CI: 80.3–82.9) of participants self-reported food insecurity. Food insecurity was highest in March (69%) as opposed to the post-harvest period (50% in September). The prevalence of stunting in the sample was 44% (95% CI: 42.3–45.6) and varies seasonally. Wasting prevalence in children was found to be higher in poor and food-insecure households.</p>
<p><b>Ardalan et.al 2019</b></p>	<p>A review was conducted to investigate the impact of climate change on community health and resilience in Ethiopia.</p>	<p>MEDLINE, EMBASE, PubMed, Scopus and Google Scholar were searched. Articles included were published in English between January 2004 and December 2018.</p>	<p>Twenty articles were selected and included. The most relevant findings are as follows: In a study from 2011 (n=614 households), in Southern Ethiopia, 54.1% of households experienced food insecurity. In the same year and region, a separate study (n= 1094 households) showed moderate and severe hunger was 29% and 5.6% respectively. Similar findings emerged in studies conducted in Northern and Eastern Ethiopia.</p>
<p><b>Mortality:</b></p>			
<p><b>Delbiso et.al 2017</b></p>	<p>An ecological study to investigate the impact of drought on child mortality, from 2009 to 2014, on 55219 Ethiopian children under the age of five.</p>	<p>Under-five death rate (U5DR) data were extracted from the Complex Emergency Database (CE-DAT). Based on the inclusion criteria (Appendix E.1), 88 surveys, from 7 regions, were included. Drought exposure measured using a Standardized Precipitation Evapotranspiration Index (SPEI). Short- and long-term drought was defined by calculation 3-month and 12- month SPEI's.</p>	<p>95.1% of surveys conducted in areas experiencing food insecurity, with 56.8% and 67% reporting short- and long-term drought respectively. The study found that the pooled U5DR was 0.323/10,000/day (95% credible interval, CrI: 0.254–0.397). Drought, both long- and short-term were not associated with U5DR. U5DR was higher in surveys reporting minimal food insecurity compared to those surveys reporting intense food insecurity, 0.722 (95% CrI: 0.317–1.458) and 0.287 (95% CrI: 0.205–0.388).</p>

**Anaemia:**

<b>Gari et.al 2017</b>	A cohort study to investigate childhood anaemia (n = 6116) in a drought-affected in Oromia Regional State in Ethiopia, from 2014-2015.	Haemoglobin levels were measured, and questionnaires were used to collect socio-demographic and economic data. Anthropometric measurements for malnutrition included weight, height/length of children.	The dynamic cohort's incidence rate after the 1-year follow-up was 30 cases/100 children years of observation (95% CI, 28-32). The hazard ratio for anaemia for children having malaria was 10.4. There were also other risk factors associated with anaemia with an increased wasting, stunting and underweight during the cohort period.
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**Disability:**

<b>Dinkelman 2015</b>	A cohort study investigating disability due to drought shocks in South African homelands, from 1948 to 1986.	Census data on disability was obtained. Place of residence and birth was obtained from participants. Drought was measured using rainfall data from 1000 local weather stations. Drought measures specific for district and year were constructed using the Standardized Precipitation Index (SPI).	Exposure to drought in infancy increased mental and physical disabilities. The total prevalence of disability was 5.2%. Visual, physical and speech or hearing disabilities accounted for 2.3%, 1.4% and 1.1%, respectively and mental disabilities, 07%.
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### 3.1.1 Malnutrition

One ecological study (Bauer and Mburu 2017) and two cross-sectional studies (Belay et.al 2019, Lazzaroni and Wagner 2016) conducted in Kenya, Ethiopia and Senegal investigated the effect of drought on malnutrition; all three found a high prevalence of malnutrition during periods of drought. Two studies had a small sample size (Bauer and Mburu 2017, Belay et.al 2019). Validated methods for malnutrition assessment were used in all three studies including MUAC measurements in 2 studies (Bauer 2017, Belay 2019) and HAZ, WAZ and WHZ measurements in one (Lazzaroni and Wagner, 2016)). Lazzaroni and Wagner (2016) did not indicate whether data was collected on pre-existing medical conditions. Bauer and Mburu (2017) used a more objective measure for drought i.e. NDVI, while the other two studies relied on participant recollection on the occurrence of drought (Belay et.al (2019), Lazzaroni and Wagner (2016)).

Other factors, such as socioeconomic status of households, that can affect child health, particularly nutritional health, are mentioned in Bauer and Mburu (2017) study. The improvement in child health seen in Lazzaroni and Wagner (2016) highlights the importance of improved access to water and sanitation and the role of international relief agencies in combatting the adverse effects of climatic events. Drawing on these three studies as present-day evidence on the landscape of malnutrition in an African context suggests that the evidence on the effect of drought on malnutrition is limited.

### **3.1.2 Wasting, underweight and stunting:**

Four studies investigated the impact of drought on wasting, underweight and stunting (Kinyoki et.al, (2016), Kinyoki et.al (2017), Belayneh et.al, (2019) and Ardalan et.al (2019)) in Somalia and Ethiopia. Belayneh et.al, (2019) had a small sample size and food insecurity was attributed to the past contextual information regarding the susceptibility of Ethiopia to episodes of drought. Two studies (Kinyoki et.al, (2016), Kinyoki et.al (2017) used EVI as a reliable proxy measure for drought. All the studies used the same measure for wasting, underweight and stunting.

The review paper by Ardalan et.al (2019), included three separate studies that assessed child health and two studies that looked at food insecurity. While the study follows a systematic review process, it is still possible for selection bias to occur during the screening process and relevant studies may have been excluded. The inclusion and exclusion criteria are not listed in the paper and the keywords used are non-specific. It is therefore difficult to assess the rigorousness of their methodology.

However, all four studies found a prevalence of wasting, stunting and underweight in children living in drought-prone areas, where food insecurity is increased during periods of drought, but the evidence can still be considered insufficient due to the limitations indicated above. Furthermore, there are long- and short-term effects of drought on childhood outcomes. Wasting occurs in instances of acute food insecurity and stunting occurs following long-term nutritional insufficiencies. While both parameters are an indication of nutritional health, the timeframe attached to each may differ.

### **3.1.3 Mortality:**

One ecological study in Ethiopia (Delbiso et.al (2017) did not find an effect of drought on U5DR's in areas of high levels of food insecurity. The data was extracted from a

national database using strict inclusion criteria and a reliable drought measure (SPEI) was used. The authors list several confounding factors that may have influenced the U5DR found in this study, such as accessibility of international food aids.

#### **3.1.4 Anaemia:**

A single cohort study (Gari, et.al, 2017) investigated the incidence of anaemia in a drought and malaria-stricken state in Ethiopia. Anaemia was diagnosed using objective parameters i.e. blood haemoglobin levels. An annual increase in the incidence of anaemia was found but the result could have been confounded by the high malaria burden in the region.

#### **3.1.5 Disability:**

A single large cohort study (Dinkelman, et.al 2015), based on 38 years of data, found an increased incidence in disabilities associated with drought among children. In this study, nutrition-related disability is defined by childhood exposure to drought resulting in the development of physical or neurological disabilities later in life. Disability was based on census data and drought on area-specific rainfall data. The evidence presented in this study is limited and may have been influenced by contextual factors (i.e. sample specifications included participants who lived in homelands in South Africa during the *apartheid* era), thereby limiting generalizability.



### 3.2 Drought and food consumption:

Following on from the previous section's discussion of how drought directly influences health through driving food insecurity, this section explores indirect ways in which health is influenced by drought-related food insecurity. These indirect effects on health occur through diverse food consumption pathways (figure 2) including (a) engineered drought-tolerant crops that are neurotoxic and (b) micronutrient deficient foods from donor agencies. Two studies (Table 2) explored the effects of drought and food consumption on the prevalence of (1) angular stomatitis; and (2) motor neuron diseases. The evidence from the two studies reviewed, an association between drought and food consumption was weak; however, other articles may exist for Africa and provide different findings.

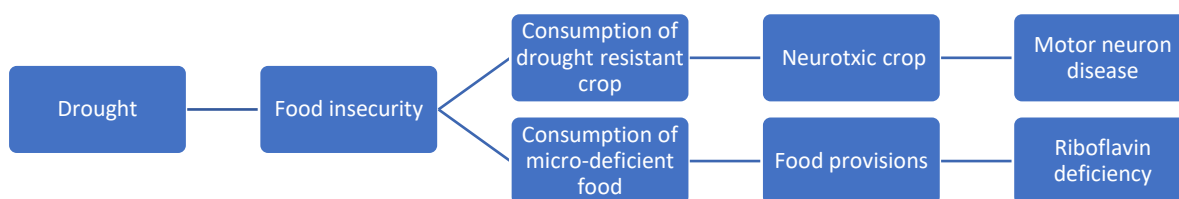


Figure 2: Drought has been shown to cause instances of food insecurity and crop damage, which affects the types and quality of food consumed, consequently causing adverse health effects.

Table 2: Studies exploring the adverse health effects associated with food consumption, during periods of drought:

Author name(s) and Year of publication:	Study population and design:	Methods:	Findings:
<b>Angular stomatitis:</b>			
<b>Nichols et.al 2013</b>	A cross-sectional study investigated a suspected outbreak of riboflavin deficiency (n =179 172) in Nakapiripit, from 2009 to 2010.	Participants underwent rapid assessment, and/or mass screening for angular stomatitis (AS). Additionally, 76 participants were tested for riboflavin deficiency. Food ration analysis was conducted using food planning and distribution records of an adjacent district.	0.2% (n=399) of participants showed signs of AS. 86.8% of those tested participants (n=78), were riboflavin deficient. Food ration analysis showed that only 55% of distributions met less than half of the required daily allowance (RDA) of riboflavin.
<b>Konzo and neurolathyrism:</b>			
<b>Ngudi et.al 2012</b>	A review to investigate the interest in 3 motor neuron diseases (i.e. konzo, neurolathyrism, HTLV-1 associated myelopathy/Tropical spastic).	Web of Science and Pubmed databases were searched. The search was limited to 1990-2010. Authors compare how many published articles their search revealed.	There were 84, 99 and 504 articles on Konzo, neurolathyrism and HAM/TSP respectively. No increase in the number of publications of the Konzo and neurolathyrism compared to HTLV- was found, with limited interest in motor neuron diseases. Disease prevalence is also not discussed in the results of the study.

### **3.2.1 Angular stomatitis (AS)**

One study investigated AS in relation to food provisions in Uganda (Nicholas et al, 2013). AS was based on rapid screening for the whole cohort and blood riboflavin deficiency in a small convenience sample of participants. The region had experienced three successive years of climatic shocks and crop failure and this contextual information was used the frame the study results, linking it to drought. Several potential confounders were not accounted for and there was no measurement for drought exposure in this study. Therefore, the results of this study are limited.

### **3.2.2 Konzo and neurolathyrism:**

Ngudi et al (2012) is a review study aimed to assess the scientific interest in two motor neuron diseases i.e. Konzo and neurolathyrism, based on the number of publications for the diseases over the past 21 years. No studies on the effect of drought on these diseases were found. The results of this study, linking drought and motor neuron diseases, are limited.

### **3.3 Drought and water-borne, water-washed and water-related diseases:**

Drought and floods could reduce the availability of safe drinking water and result in poor hygiene practices (Davies et. al, 2015) which could increase in the incidence of diarrhoeal and other diseases (Franchini and Mannucci, 2015). Nine studies (Table 3) explored the effects of drought on (a) cholera outbreaks (n=2); (b) diarrhoeal disease prevalence (n=2); (c) protozoa parasite transmission; (d) scabies outbreaks; (e) trachoma prevalence; (f) vector-borne disease outbreaks and (g) malaria-related mortality. From these articles that were reviewed, the evidence of an association was weak; however, other articles may exist for Africa and provide different findings.

Table 3: Studies exploring the association between drought and water-borne, water-washed and water-related diseases.

Author name(s) and Year of publication:	Study population and design:	Methods:	Findings:
<b>Cholera:</b>			
Rebaudet et.al 2013	A systematic review of the environmental determinants of cholera outbreaks in Africa.	Pubmed, Promed-mail, Google and Google Scholar databases were searched for English and French articles published in 1970-September 2012, including the reference list of textbooks. A total of 113 articles and 11 alerts were included.	In the last 20 years, most cholera cases in Africa were reported around the African Great Lakes Region and the Lake Chad Basin, reportedly overpopulated, with many refugee camps and has frequent movement. Precipitation was associated with cholera epidemics in Uganda, Zambia and Malawi and drought in Sahel. However, droughts have occurred during both the rainy seasons and drought.
Rieckmann et.al 2018	An ecological study on the association between droughts and floods and cholera outbreaks in 41 Sub-Saharan African countries from 1990 to 2010.	EM-DAT International Disaster Databases were used to extract cholera, droughts and floods data. Detailed case definitions for cholera outbreaks were used (Appendix E.3).	Within the study period, 276 cholera outbreaks reported with 118 during drought episodes. Twenty-five cholera outbreaks occurred during drought periods, 24 during flood periods, 10 during both drought and flood periods and the remainder (217) began during drought/flood-free periods. The number of outbreaks per drought periods was 4.5 times larger than that per flood periods and 4.3 times larger than per drought/flood-free periods.
<b>Diarrhoeal diseases:</b>			
Alexander et.al 2013	An ecological study on climate change effects on diarrhoeal disease in Botswana.	Temperature, vapor data and climatic index for aridity were extracted from the Climate Research Unit (CRU) TS 3.10, for 30 years. Diarrhoeal case incidence data was extracted from annual reports of healthcare facilities. The classification of diarrhoeal disease was based on national and international guidelines.	The annual average rainfall was 36.97mm ± 44.15 mm, with monthly rainfall ranging from 0-254mm. Diarrhoeal cases were 20% higher in the dry season compared to the wet season. This could be due to favourable climatic conditions for flies.

<p><b>Bandyopadhyay et.al</b> 2012</p>	<p>An ecological study on the impact of rainfall and temperature variation on diarrhoeal prevalence in 13 Sub-Saharan African countries.</p>	<p>Data was taken from the Demographic and Health Surveys (DHS) for Sub-Saharan Africa. Lagged precipitation and temperature data, obtained from the Africa Rainfall and Temperature Evaluation System (ARTES), were constructed against diarrhoeal disease prevalence.</p>	<p>The average diarrhoeal prevalence was 22.9%, increasing in children &lt;5 years during dry periods. During rainfall periods, diarrhoeal prevalence decreased by 3%. A 1°C increase in maximum temperature increased diarrhoeal prevalence by 1%.</p>
<p><b>Protozoan parasites:</b></p>			
<p><b>Ahmed et.al</b> 2018</p>	<p>A review study on the impact of water crises and climate changes on the transmission of protozoan parasites in Africa</p>	<p>Databases such as Scopus, PubMed, Google Scholar, (see Appendix E.3 for full list) were searched for articles published from 1982 to 2018.</p>	<p>One hundred and twenty studies, from 21 African countries, were included. <i>Cryptosporidium</i> spp., <i>G. duodenalis</i>, and <i>Entamoeba</i> spp. was the most commonly found micro-organism in water bodies (found in 12, 16, and 10 African countries respectively). <i>Acanthamoeba</i> and <i>Naegleria</i> spp. were reported in 40 of the included articles. <i>Entamoeba</i> spp. was in drinking water of 3 countries. Reports on other WBP were scarce.</p>
<p><b>Scabies:</b></p>			
<p><b>Enbiale and Ayalew</b> 2018</p>	<p>A cross-sectional study in 68 districts in the Amhara region of Ethiopia on scabies outbreaks in drought-affected areas.</p>	<p>Scabies outbreaks data was collected during a drought period (October to December 2015), with all household members screened, and information on demographic factors and causative factors collected.</p>	<p>1,125,770 individuals were screened, in which 379,000 confirmed scabies cases were found. The odds ratio for children and young adults for developing scabies was 2.5 compared to adults. The overall scabies prevalence ranged from 2% to 67% with a median prevalence of 33.5 (IQR 19–48%). In cases, 30% had a secondary bacterial infection and 75.1% had family members who were affected.</p>

**Trachoma:**

<p><b>Ramesh et.al</b> 2013</p>	<p>A systematic review of the impact of climatic risk factors on the prevalence, distribution, and severity of acute and chronic trachoma in Africa.</p>	<p>Various databases were searched (See Appendix E.3 for full list). The diagnosis of cases was based on the World Health Organization (WHO) guidelines. The study period was from January 1950 to 1 April 2012.</p>	<p>Eight cross-sectional studies, conducted in Ethiopia, Mali, Sudan, Tanzania and Burkina Faso, were selected. In Mali, one study found a decrease in trachoma prevalence with a decrease in the annual temperature, whilst the other study found the opposite association. Another study showed a decrease in the number of rainfall days increased the risk of active trachoma in children (odds ratio 1.59, 95% CI 1.03–2.44). One study in Burkina Faso found that a 1 °C rise in temperature resulted in a 43% lower disease risk. A study in Sudan found a 100mm decrease in rainfall resulted in a 79% higher trachoma prevalence.</p>
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**Vector-borne diseases:**

<p><b>Anyamba et.al</b> 2014</p>	<p>An ecological study on recent weather extremes and impacts on agricultural production and vector-borne disease outbreak patterns in Texas, Russia, Africa, South Africa, Australia.</p>	<p>Rainfall, vegetation and temperature data were extracted from the Global Precipitation Climatology Project, Normalized difference vegetation index (NDVI) and land surface temperature (LST) measurements, respectively. Vector-borne disease outbreak was monitored and evaluated using various health organization records.</p>	<p>Between December 2010-February 2011, East Africa experienced drought (rainfall &lt; 85% of normal). Persistent, above-normal land surface temperature (5–20 °C) and drought was associated with a large-scale dengue outbreak resulting from increased mosquito populations in Mogadishu, Kenya and Somalia.</p>
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**Malaria-related mortality:**

<p><b>Bakshi et.al</b> 2019</p>	<p>An ecological study (2008-2009) on the link between climate variability and mortality in Kenya, Mali and Malawi.</p>	<p>Mortality, demographic and climate data were obtained using the TerraPop data extraction system. Malaria and HIV information extracted from the Malaria Atlas Project and demographic and health surveys (DHS), respectively. For temperature, one standard deviation (SD) above or below the normal was classified as a heatwave or “cold snap”, respectively. Drought was defined by precipitation below normal by one SD. The climate impact index was a combination of drought and heatwaves, which often occur jointly.</p>	<p>Heatwaves were not associated with an increase in mortality rates. In Kenya only, cold snaps were associated with an increase in mortality (0.40, p&lt;0.001). Drought was associated with an increase in mortality in Malawi (0.08, p &lt; 0.01), due to the exacerbation of food insecurity. In Kenya only, there was no effect of drought on mortality rates in regions of low HIV/AIDS prevalence. In Kenya only, during drought, where malaria prevalence is low, mortality rates increased.</p>
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### **3.3.1 Cholera:**

Droughts are linked to increased risk of diarrhoeal disease, including cholera, due to decreased water for hygiene purposes. One ecological study and one review paper investigated the association between drought and cholera. The systematic review by Rebaudet et al (2013) included 123 studies but the data was mostly ecological and conflicting evidence was found on the effect of drought on cholera. Factors such as overpopulation, refugee camps and frequent movement could also confound the results.

Rieckmann et al (2013) found an increase in the prevalence of cholera outbreaks during drought. There was a clear case definition of cholera and data on cholera, droughts and floods were sourced from a reliable database (EM-DAT). However, it is possible that cholera cases captured in the drought/flood-free periods may be cases that occurred during a drought period. Relatedly, an ecological study is prone to ecological fallacy in which biases may arise when heterogenic country data is used to conclude the risk of cholera outbreaks in countries with limited or no data on droughts, floods and cholera outbreaks (Schwartz, 1994). The evidence on the effect of drought on cholera can, therefore, be described as limited.

### **3.3.2 Diarrhoeal disease:**

Two ecological studies (Alexander et.al, 2013 and Bandyopadhyay et.al, 2012) investigating the prevalence of diarrhoeal disease in Botswana and Sub-Saharan Africa found an increase in diarrhoeal disease during dry seasons, when rainfall was decreased, compared to wet seasons. Alexander and colleagues (2013) used clear case definitions for diarrhoea but Bandyopadhyay et.al (2012) did not. Both studies used objective climatic data. Alexander et.al (2013) accounted for various confounding factors while Bandyopadhyay et.al (2012) only considered one. Overall the ecological study design limits the strength of the results and the evidence is limited.

### **3.3.3 Protozoan parasites:**

A single paper by Ahmed et.al (2018) reviewed the literature on the impact of climate change, specifically water crisis, on the transmission of protozoan parasites. The review includes 120 studies in 20 countries but merely reports on the presence of WBP in water bodies rather than the association to drought. While Ahmed et.al (2018) explain the biological plausibility of the association between drought and WBP outbreaks, the evidence presented is limited.

### **3.3.4 Scabies:**

A single large cross-sectional (Enbiale and Ayalew, 2018) study investigated descriptive factors on scabies during a drought period. Cases were diagnosed based on the clinical history and skin examination only. Scabies manifestation can mimic other skin conditions such as folliculitis and eczema (Walton and Currie, 2007) and cases could, therefore, be missed. The study merely showed a high prevalence of scabies during a drought period.

### **3.3.5 Trachoma:**

A single paper by Ramesh et.al (2013) reviewed the association between climatic variables and the prevalence of trachoma. Eight cross-sectional studies were included. The study results focus mainly on temperature, altitude and rainfall, with no specific reference to drought. The study found some suggestive results of increased prevalence of trachoma with increasing temperature and decreasing rainfall although one study produced conflicting results.



### **3.3.6 Vector-borne diseases:**

A single ecological study Anyamba et.al (2014) reported the occurrence of dengue outbreaks during a period of drought in three East African countries, using weather data and health monitoring records. Other aetiological disease factors, the singularity of the study and the study design's susceptibility to ecological fallacy might be the reason for the observed findings, therefore, the results presented are limited.

### **3.3.7 Malaria-related mortality:**

One ecological study Bakshi et.al, (2019) found inconsistent results that drought increased malaria-related mortality in Kenya, Mali and Malawi. The outcome measure was dependent on participant recall of household deaths and the cause of death was not specified. Confounding by non-climatic factors was controlled for and the results showed that pre-existing conditions such as HIV and malaria affect the association between drought and mortality. This study also discusses the impact of contextual factors on mortality, which could explain the different mortality profiles.

### **3.4 Drought and health behaviours:**

Drought affects health practices and health-seeking behaviours of individuals. Three studies (Table 4) explored the effects of drought on (1) health perceptions and health seeking behaviours; (2) HIV prevention and care behaviours; and (3) family planning practices. Findings from these studies are based on qualitative data and therefore the robustness of the evidence varies. The three articles that were reviewed, showed a weak association between drought and health behaviours; however, other articles may exist for Africa and provide different findings.

Table 4: Studies exploring health behaviours during periods of drought:

Author name(s) and Year of publication:	Study population and design:	Methods:	Findings:
<b>Health perceptions and Health seeking behaviours:</b>			
Heaney and Winter 2016	A cross-sectional study in Tanzania investigated the health perceptions and health-seeking behaviours of the Maasai population	Interviews were conducted on migrant and non-migrant groups, during July-August 2013. Participants were matched according to demographics and location. Participants were asked mainly open-ended questions.	Physical health was of more importance in the non-migrant group. In the migrant group (those displaced due to drought), mental health was of greater importance and poor mental wellness was attributed to social and emotional distress such as loneliness. Despite the acknowledgement that mental health was a concern, participants in both groups only sought help for physical ailments.
<b>HIV prevention:</b>			
Low et.al 2019	A cross-sectional study in Lesotho investigated the association between severe drought and HIV prevention and care behaviours (ages 15-59 years)	Surveys were conducted between November 2016 and May 2017 as part of the Lesotho Population-Based HIV Impact Assessment (LePHIA) project, in 418 areas. The household heads answered socioeconomic and demographic questions and consented to HIV testing. A total of 8824 interviews and 11 682 HIV tests were conducted.	Approximately 94% of all households were in drought areas. During periods of drought, females from urban areas were 5 times more likely to engage in selling sex, 3 times more likely to experience forced sex and in females in rural areas, condom use was reduced (OR 0.70, 95% CI 0.54–0.92, p= 0.01). The prevalence of HIV in urban and rural areas was 26.9% and 24.7%, respectively, with a higher prevalence in females in both areas. There was no association between drought and HIV in older individuals.
<b>Women’s health- Family planning:</b>			
Kock and Prost 2017	A cross-sectional study investigating the thoughts of men on a Population Health and Environment (PHE) Programme in Rural Kenya.	Participants (n=27 males) from the Samburu population, recruited using quota sampling, participated in semi-structured interviews and focus group discussions regarding their views on drought and the PHE family planning programs.	All participants acknowledged that they were entirely reliant on natural resources for their livelihood and that having smaller family sizes would be beneficial for the environment and subsequently for their survival. Eight of the nine elders (>45 years) expressed concern on how difficult it is to sustain a larger family, given the increased occurrence of drought periods.

### **3.4.1 Health perceptions and Health seeking behaviours:**

A single study (Heaney and Winter, 2016) assessed the health perceptions and health-seeking behaviours of migrant and non-migrant participants affected by drought. While perceptions and behaviours differ between the two groups, it is important to note that this study had a small sample size (n=28) and the reported responses from these participants may not be representative of all groups affected by drought. Furthermore, health seeking behaviours may be influenced more by cultural and contextual factors, which are unrelated to the occurrence of drought in this study sample.

The authors designed questions based on literature and illness behaviour frameworks. The use of mainly open-ended questions and the ability to answer in the locally spoken language (in this case, Swahili) allowed participants to answer questions in a less restricted manner. The use of a translator in this study could limit the validity as bias could be introduced when translating participant responses. To combat this, interviews were audio-recorded and transcribed, verbatim. This limits the introduction of bias in the data capturing and analysis process.

### **3.4.2 HIV prevention:**

One cross-sectional study with a large, randomly selected sample (Low et al,2019) investigated factors associated with prevention and care behaviours related to HIV, in a drought period, in Ethiopia. No evidence on the effect of drought on HIV prevention was produced as there was no comparison to a non-drought period. The study indicated that there was an increase in risky behaviours e.g. selling sex, particularly in communities that are dependent on environmental resources for sustenance.

### **3.4.3 Women's health- family planning:**

One small study (Kock and Prost, (2017) investigated the perceptions of men on the impact of drought on family planning via focus group discussions and semi-structured interviews. Sampling bias is more likely to occur with quota -sampling employed in the study (Sharma, 2017). The evidence from such a study, while providing useful individual insights, has low internal validity and cannot be generalized to other populations. The study highlights the importance of thinking beyond the immediate and direct impacts of climate change. Reproductive health should be prioritized before a climatic shock occurs to circumvent additional pressures being placed on already vulnerable population groups.

## **4. DISCUSSION:**

### **4.1. Summary of main results:**

The 24 articles included in the review provided evidence classified into 4 main categories: (1) drought and nutritional health including malnutrition, poor childhood health outcomes (wasting, stunting and underweight), mortality, anaemia, and nutrition related disability; (2) drought and food consumption including micronutrient deficiencies and motor neuron diseases; (3) drought and water-borne, water-washed and water related diseases including cholera outbreaks, diarrhoeal diseases, protozoa parasite transmission, scabies outbreaks, trachoma, vector-borne disease outbreaks and malaria-related mortality; and (4) drought and health behaviours including health perceptions and health seeking behaviours, HIV prevention and care behaviour and family planning practices.

The evidence on the effect of malnutrition on drought in Africa was limited to 3 studies (Bauer and Mburu 2017, Belay et.al 2019, Lazzaroni and Wagner 2016)) with several methodological weaknesses including a lack of comparison to non-drought periods. Although 4 studies (Kinyoki et.al, (2016), Kinyoki et.al (2017), Belayneh et.al, (2019) and Ardalan et.al (2019)) found a high prevalence of wasting, stunting and underweight in children living in drought-prone areas due to food insecurity, the evidence was limited due to several methodological weaknesses including again, a lack of comparison to non-drought periods. One ecological study in Ethiopia (Delbiso et.al (2017) did not find an effect of drought on U5DR's in areas of high levels of food insecurity as the data might have been affected by international food aid. A single cohort study (Gari, et.al, 2017) investigated the incidence of anaemia in a drought and malaria-stricken state in Ethiopia but the result could have been confounded by the high malaria burden in the region. A single large cohort study (Dinkelman, et.al 2015) based on 38 years of data found an increased incidence in disabilities associated with drought among children but the evidence presented in this study can be described as insufficient as it may have been influenced by contextual factors; generalizability may be limited.

One study investigated AS in relation to food provisions in Uganda (Nicholas et al, 2013) but several potential confounders were not accounted for and there was no measurement for drought exposure in this study. One review study aimed to assess the scientific interest in two motor neuron diseases i.e. Konzo and neurolathyrism, but no studies on the effect of drought on these diseases were found. Both studies show a insufficient link between drought and food consumption.

The evidence on the association between drought and cholera included mostly ecological studies (Rebaudet et al (2013) and Rieckmann et al (2013)), with the study design having inherent methodological limitations, and both studies reporting conflicting

evidence. Two ecological studies (Alexander et.al, 2013 and Bandyopadhyay et.al, 2012) which investigated the prevalence of diarrhoeal disease in Botswana and Sub-Saharan Africa found an increase in diarrhoeal disease during dry seasons, when rainfall was decreased, compared to wet seasons. A single review of 120 studies in 20 countries only reported on the presence of waterborne protozoa (WBP) in water bodies rather than the association to drought. A single large cross-sectional (Enbiale and Ayalew, 2018) study merely showed a high prevalence of scabies during a drought period. Ramesh et.al's review (2013) on eight cross-sectional studies suggested an increased prevalence of trachoma with increasing temperature and decreasing rainfall however one included study produced conflicting results. A single ecological study (Anyamba et.al, 2014) found the occurrence of dengue outbreaks during periods of drought in three East African countries but there is the possibility that other aetiological disease factors could explain the observed findings. One ecological study (Bakshi et.al, 2019), conducted in Kenya, Mali and Malawi, found inconsistent results that drought increased malaria-related mortality in the three African countries investigated. Only in Kenya was a low prevalence of malaria associated with an increase in mortality rates during periods of drought.

A single study (Heaney and Winter, 2016) assessed the health perceptions and health seeking behaviours of migrant and non-migrant participants affected by drought. While the study provides useful insights into the health seeking behaviours of this sample, generalizability is limited as confounding factors may exist. One cross-sectional study with a large random sample (Low et al,2019) investigated factors associated with prevention and care behaviours related to HIV in a drought period in Ethiopia. No evidence on the effect of drought on HIV prevention was produced as there was no comparison to a non-drought period. One small study (Kock and Prost, 2017)

investigated the perceptions of men on the impact of drought on family planning but the evidence from such a study, while providing useful individual insights, has low internal validity and cannot be generalized to other populations.

The most common weakness found in studies investigating the health effects due to drought included in the review was the lack of comparison to a non-drought period.

Second, the feasibility of longitudinal studies related to the health effects associated with drought might be challenging as the onset, end and duration of a drought episode is often unpredictable. Seven studies (29%) used a cross-sectional study design and seven studies (29%) used an ecological study design; both study designs have inherent weaknesses which lower the strength of the evidence. Third, the studies on most health outcomes were not conducted in many African countries. The country most represented in this review was Ethiopia, with 29% of the studies conducted in this region. This could be due to better public health monitoring and evaluation initiatives established in Ethiopia compared to other regions in Africa, or it might be due to different relative rules with regards to research ethics oversight and patient access in this country. Fourth, several studies did not account for important confounding factors and were influenced by contextual factors. Fifth, conflicting evidence was found for several health outcomes. There is thus a need for studies addressing the weaknesses indicated above.

Nevertheless, the results of this review do provide some insight into factors that affect health and vulnerable groups most impacted by drought.

#### **4.2 Risk factors that increase susceptibility to drought-related adverse health effects, vulnerable groups and vulnerability index:**

The results from the present review highlighted underlying physical or environmental factors that could have an impact on the health of a drought-stricken community.

Political tensions, such as civil conflict, the ability of a country to draw international aids

in times of conflict, existing burden of diseases (e.g. high number of malaria cases) and lack of access to clean water and proper sanitation can affect health in different ways. In children, the age and sex of the child (male children identified as being more prone to malnutrition), history of past or present infections, maternal presence in households, education level of the parent and financial status of the household the child resides in, may increase the susceptibility of a child to adverse health outcomes.

Those most susceptible to adverse health effects from drought episodes are often those with a low adaptive capacity. These include children, the elderly, refugees, those forced to migrate out of homelands due to climate-driven loss of land and/or livestock and individuals from low socioeconomic backgrounds who lack access to basic amenities such as safe drinking water. The present study only identifies some vulnerable groups, but not all. From those identified, the most important health effects have been emphasized e.g. in children malnutrition, wasting, stunting and underweight are the most prominent health effects associated with drought. As such, these are key indicators that can be used to begin to develop a broad framework for a vulnerability index and implications for future research.

As seen from the review results, evidence on the direct association between drought and adverse health effects is insufficient. Given the increase in the frequency of drought episodes, more objective and robust studies are needed to support the association between the two variables. This would include, in part, the use of effective and reliable drought monitoring indices such as SPEI. The review results also do not mention what public health measures are currently in place to circumvent the occurrence of adverse



health effects in response to climatic shock. Documentation of these measures allows for a government to equitably distribute resources to those most vulnerable to the adverse health effects of drought. There are no studies that mention the effects of drought on the elderly or those with disabilities, who are often more susceptible to health complications. To build a comprehensive health vulnerability index for drought, it is vital that all vulnerable groups must be identified and studied.

#### **4.3 Comparison of results with the previous review by Stanke et.al (2013):**

The databases searched in the review are different from those searched in the Stanke et.al (2013) study (MEDLINE, CINAHL, Embase, PsychINFO, Cochrane Collection and reference lists). The authors for the Stanke et.al (2013) study do not provide reasons for the databases chosen. The present study database selection was decided upon based on the most widely used databases e.g. PubMed and the relevance of published work to the African continent. To avoid repetition of study results, the search was limited to 2012-2019, to ensure that only articles published after the Stanke et.al (2013) review were included. A total of 87 papers were included in the previous review and 24 papers in the present study which may reflect the considerably shorter period of included studies between this study and Stanke et.al (2013). The adverse health effects found in the previous review, and which were not found in the present, include Vitamin A deficiencies, scurvy, Veno-occlusive liver disease, selenium toxicity, urinary thiocyanate, tick-borne borreliosis, malaria-related mortality, smallpox, airborne and dust-related diseases and aflatoxicosis. The present study found studies investigating additional health effects including anaemia, disability, angular stomatitis, scabies, trachoma, HIV transmission and female reproductive health. The difference between the number of health effects reported in the previous and present review could be due to (1)

disease profiles in Africa may differ to those in other regions of the world; (2) better preparedness of regions prone to drought and the associated adverse health effects since 2012; (3) under- or over-reporting on health conditions in Africa and; (4) shift in focus to more preventative measures to reduce the effects of climate change.

Furthermore, articles published in other languages, particularly French which is the language in which many African articles are written, were excluded. From the articles that were reviewed, the evidence of an association was limited; however, other articles may exist for Africa and provide different findings. This was a study limitation in both the Stanke et al (2013) and the present study.

## **5. CONCLUSION:**

The results of the above study showed that individual studies did not provide strong evidence for the link between drought and the listed adverse health outcomes.

However, this review does provide useful insights into what possible health outcomes could arise in individuals affected by drought and implications for research. Firstly, the increase in the frequency and intensity of drought calls for the development and use of more objective drought monitoring systems. Underreporting of health conditions may also be problematic in certain settings and therefore better public health surveillance systems are essential. Secondly, studies showed vulnerabilities are linked to socioeconomic factors and therefore future studies could assess the extent to which these factors affect health in the context of drought. Lastly, the impact of climate change on mental health and health behaviours, such as risky sexual behaviours, should be explored in greater depth, particularly in regions with a high HIV/AIDS burden.

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# **Part C: Appendices**

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## Appendix A: Electronic databases and search strategies

### A.1 Electronic search of databases for published, peer-reviewed articles and keywords used.

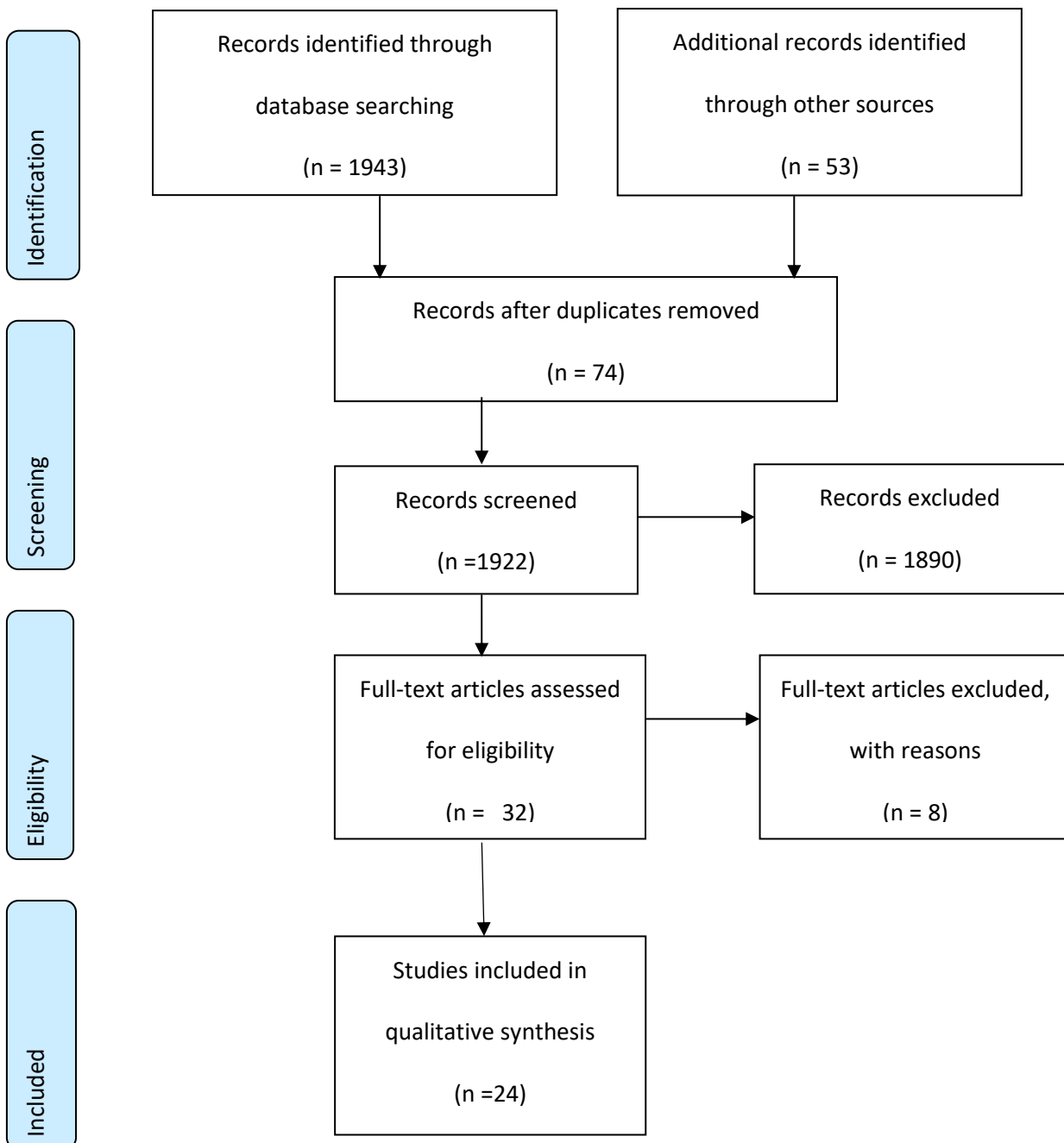
	Database:	Keywords:
1.	PubMed	droughts OR water vulnerability OR water insecurity OR water shortage OR reduced rain OR reduced water intake OR desertification OR low rainfall OR poor rainfall OR rainfall deficit OR arid conditions OR dry weather conditions AND Health Status OR health OR public health OR risk factors OR Health vulnerability OR health status OR health consequences OR health impact OR health effects OR health risk OR health risks OR risk exposure OR risk factors NOT Animals NOT humans 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))) AND ( "2012/01/01"[PDat] : "2109/12/31"[PDat] ) AND English[lang])
2.	Scopus and Africa Wide	droughts OR water AND vulnerability OR water AND insecurity OR water AND shortage OR reduced AND rain OR reduced AND water AND intake OR desertification OR low AND rainfall OR poor AND rainfall OR rainfall AND deficit OR arid AND conditions OR dry AND weather AND condition AND health AND status OR health OR public AND health OR risk AND factors OR health AND vulnerability OR health AND status OR health AND consequences OR health AND impact OR health AND effects OR health AND risk OR health AND risks OR risk AND exposure OR risk AND factors AND NOT animals 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

		<p>Tanzania OR Togo OR Tunisia OR Uganda OR "Western Sahara" OR Zaire OR Zambia OR Zimbabwe</p> <p>Filters:</p> <p>Limit year of publication: 2012-2019</p> <p>Limit language: English</p>
3.	Web of Science	<p>( droughts OR water AND vulnerability OR water AND insecurity OR water AND shortage OR reduced AND rain OR reduced AND water AND intake OR desertification OR low AND rainfall OR poor AND rainfall OR rainfall AND deficit OR arid AND conditions OR dry AND weather AND condition ) AND ( health AND status OR health OR public AND health OR risk AND factors OR health AND vulnerability OR health AND status OR health AND consequences OR health AND impact OR health AND effects OR health AND risk OR health AND risks OR risk AND exposure OR risk AND factors ) 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 )</p> <p>Filters:</p> <p>Limit to 'Humans'</p> <p>Limit year of publication: 2012-2019</p> <p>Limit language: English</p>

## A.2. Electronic search of grey literature with associated keywords:

Database:		Keywords:
1.	ProQuest	(1) "Drought" AND "Health effects" (2) "Public Health" AND "Drought" Filters: Limit year of publication: 2012-2019 Limit language: English
2.	Open Grey Open Doar	(1) "Drought" AND "Health" (2) "Drought" AND "Adverse Health effects" Filters: Limit year of publication: 2012-2019 Limit language: English
3.	Paper First Proceeding First	"Drought" AND "Adverse Health Effects" Filters: Limit year of publication: 2012-2019 Limit language: English
4.	Google Scholar	droughts OR drought OR water vulnerability OR water insecurity OR water shortage OR reduced rain OR reduced water intake OR desertification OR low rainfall OR poor rainfall OR rainfall deficit OR arid conditions OR dry weather conditions AND Health Status Filters: Limit year of publication: 2012-2019 First 100 results reviewed

## Appendix B: Prisma Flow diagram



## Appendix C: Studies excluded following a full-text review

	Author	Article Title	Reason for exclusion
1.	Mason, J.B., White, J.M., Heron, L., Carter, J., Wilkinson, C., Spiegel, P.	Child Acute Malnutrition and Mortality in Populations Affected by Displacement in the Horn of Africa, 1997–2009	No direct link to drought
2.	Mosadeghrad, A.M, Gebru, A.A., Sari, A.A., Tafesse, T.B.	Impact of food insecurity and malnutrition on the burden of Non-communicable diseases and death in Ethiopia: A situational analysis.	No direct link to drought
3.	Kim, J.J., Guha-Sapir, D.	Famines in Africa: Is early warning early enough?	Narrative review excluded
4.	Chretien, J., Anyamba, A., Small, J., Britch, S., Sanchez, J.L., Halbach, A.C., Tucker, C., Linthicum, K.J.	Global climate anomalies and potential infectious disease risks: 2014-2015.	Findings focused on climate, limited discussion on disease
5.	Senghor, B., Diaw, O.T., Doucoure, S., Seye, M., Talla, I., Diallo, A., Bâ, C.T., Sokhna, C.	Study of the snail intermediate hosts of urogenital schistosomiasis in Niakhar, region of Fatick, West central Senegal.	Animal study excluded
6.	Adeyeye, S.A.O.	Aflatoxigenic fungi and mycotoxins in food: a review.	Narrative review excluded
7.	Magnussen, A., Parsi, M.A.	Aflatoxins, hepatocellular carcinoma and public health	Narrative review excluded
8.	McMichael, A.J.	Climate Change and Children: Health Risks of Abatement Inaction, Health Gains from Action.	Narrative review excluded



## Appendix D: Data Extraction Tables

	Articles							
Author name(s)								
Year of publication								
Article title								
Study design								
Methods								
Drought exposure								
Relevance to HVI or drought outcome								
Health outcome(s) investigated								
Findings								

## Appendix E: Included articles- study details

### E.1. Drought and nutritional health:

<b>Author name(s):</b>	Bauer, JM, Mburu, S (2017)
<b>Article title:</b>	Effects of drought on child health in Marsabit District, Northern Kenya
<b>Methods:</b>	Information on child health and household factors were taken from Index-based Livestock Insurance (IBLI) child and household panel data. Surveys were conducted annually from 2009 to 2013, in 924 households in the Marsabit District. A proxy measurement for drought was obtained using the Normalized Difference Vegetation Index (NDVI). Raw data for NDVI measurements were converted to z-scores for the dry season, June to September, for each survey year. Surveys were conducted at the end of the dry season which enabled researchers to accurately capture data on child wasting. A malnutrition index was assessed using mid-upper arm circumference (MUAC). A lower MUAC z-score shows poorer health outcome, suggestive of malnutrition, and a higher MUAC z-score would suggest better health in children.
<b>Drought exposure:</b>	NDVI, a proxy measure for drought, uses the photosynthetic intensity to estimate the amount of vegetation in a given area
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, food insecurity is increased which could result in childhood malnutrition.
<b>Health outcome(s) investigated:</b>	Malnutrition using MUAC z-scores
<b>Additional findings reported</b>	The study found a positive association between NDVI- and MUAC- z-scores which suggests that in periods of food security, children experience better health. The prevalence of malnutrition in this sample, using MUAC, was found to be 20%. When further details of the child's characteristics were included in the analysis, boys are shown to be in worse health than girls. Older children are also found to have an increased risk of undernutrition, based on a higher negative association between NDVI and MUAC-z-scores in older children compared to younger children. A significant relationship was observed for ownership of a phone and child health. Authors suggest that phone ownership might allow household to obtain information on livestock prices, grazing areas and vital information on food aid programs which could improve access to food. A lower education level for the head of the household was also associated with reduced child health.

<b>Author name(s):</b>	Belay, GD, Ostadtaghizadeh, A, Khoei, EM, Ardalan, A, Hosseinzadeh-Attar, MJ, Assen, M (2019)
<b>Article title:</b>	Estimating the household drought-driven food insecurity using system dynamics model: The case of Afar national regional state of Ethiopia.
<b>Methods:</b>	The study was conducted in two randomly selected districts in Ethiopia from January 2016 to December 2018. The study used both qualitative and quantitative data to assess food insecurity caused by drought, undernutrition and policy implementation, using the Dynamics Model system, in Ethiopia. The study population included randomly selected male and female dwellers, government officials and other stakeholders. Inclusion criteria for participants includes (1) adults, children (0-59 months for assessment of malnutrition), (2) those willing to be interviewed, (3) living in the Afar region for more than 2 years and (4) those who were mentally capable to be interviewed. The sample consisted of 422 participants, in which questionnaires were administered and the Household Food Insecurity Access Scale (HFIAS) was used.
<b>Drought exposure:</b>	Household interviews and HFIAS
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, food insecurity is increased which could result in childhood malnutrition.
<b>Health outcome(s) investigated:</b>	MUAC and BMI in children under five.
<b>Additional findings reported</b>	Based on participant interviews, there was a perceived decrease in soil fertility, in which 65.2% of participants reported selling their resources during the last 10-year drought period. Reliance on food aids or food for work was found to be 41.9%. In children under five years of age, 56.8% were <60% for their weight/age, suggesting a high prevalence of malnutrition. According to participant responses, climate change was reported as the most common cause of food insecurity. Half of the participants reported receiving information on climate change from the radio.

<b>Author name(s):</b>	<b>Lazzaroni, S, Wagner, N (2016)</b>
<b>Article title:</b>	Misfortunes never come singly: Structural change, multiple shocks and child malnutrition in rural Senegal.
<b>Methods:</b>	<p>This study was conducted to assess the effects of multiple shocks on the height and weight of children living in rural Senegal. Household panel surveys were conducted in 8 regions in Senegal and information on child health was extracted. Households were randomly selected. Data were collected in two rounds; a baseline survey conducted in 2009 (May-June) and a follow-up survey in 2011 (April-May), which was after an international peak in food prices. All included households were farming households and seasonal effects were minimized as both surveys were conducted during the same season. The analysis was limited to children between 12 and 60 months and for those who had anthropometric measurements available. In 2009 and 2011, a total of 1694 and 2116 children were measured, respectively. Child nutritional status was assessed using z-scores. Weight-for-Height (WHZ), Height-for-Age (HAZ) and Weight-for-Age (WAZ) measurements were used to assess nutritional status in children. Z-scores were used to assess changes in child health; a z-score of 0 indicates no deviation in health status of the child with respect to the reference population.</p> <p>Other factors accounted for were child gender, child rank, number of individuals in the household, mother's ethnicity and polygamy. Information on climatic shock was obtained initially from participant feedback from surveys. These self-reports were then compared with other surveys conducted, in Senegal in 2010, on climate-related shock. Following this, alternative shock measures were used such as household-level climate indices. Lastly, quantile regression and sub-sample analyses assessed the robustness of the results.</p>
<b>Drought exposure:</b>	Participant reports, shock measures (e.g. household-level climate indices) and regression analysis were used to assess the occurrence of drought
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, food insecurity is increased which could result in childhood malnutrition.
<b>Health outcome(s) investigated:</b>	Child health
<b>Additional findings reported</b>	<p>The study found a negative association between the occurrence of shock (drought and purchase prices) and child health. In 2009 and 2011, 3% and 6% of households, respectively, reported the occurrence drought. Authors attribute this low percentage result to the timing of surveys i.e. they were conducted during the dry season when reduced rainfall was expected. In 2009, the mean WAZ and HAZ was 1.45 and 1.20, respectively, suggesting that the children in that sample were moderately underweight and stunted. The mean WHZ was 0.56, which is close to the international reference population, suggesting a normal weight for height in the 2009 sample. In 2011, there are significant improvements in the anthropometric measurements. The mean WAZ, HAZ and WHZ in 2011 were 0.58, 0.93 and 0.02. The possible reasons for the observed improvements in child health was attributed to agricultural and nutritional initiatives, improved access to water and sanitation, presence of the mothers in the households and mother's education. Maternal absence decreased from 5.3% to 3.5% and maternal literacy increased by 3% from 2009 to 2011. WAZ is influenced by both HAZ and WHZ and reflects both long- and short-term effects of drought on child health.</p>

<b>Author name(s):</b>	<b>Kinyoki, DK, Kandala, NB, Manda, SO, Krainski, ET, Fuglstad, GA, Moloney, GM, Berkley, JA, Noor, AM (2016)</b>
<b>Article title:</b>	Assessing comorbidity and correlates of wasting and stunting among children in Somalia using cross-sectional household surveys: 2007 to 2010.
<b>Methods:</b>	Surveys for nutritional assessments were conducted, biannually, in Somalia from 2007 to 2010. The study employed a two-stage cluster sampling methodology to select children between the ages of 6-59 months. The sample consisted of 73 778 children. Data on child health included age, gender, vitamin A supplementation in the last 6 months, vaccination history, diarrhoea and respiratory illnesses. Data on household variables include the size of the family, age structure and access to food in the past 24 hours. Data on environmental variables include rainfall, temperature, distance from water and Enhanced Vegetation Index (EVI).
<b>Drought exposure:</b>	EVI was used as a proxy for drought
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, instances of food insecurity are increased which could result in poor childhood outcomes
<b>Health outcome(s) investigated:</b>	Wasting, underweight and stunting in children
<b>Additional findings reported</b>	From a sample of 73 778 children, 21% were wasted, 31% were stunted and 58% were underweight. Nine percent of children were wasted and stunted, 29% were underweight and stunted and 20% were wasted and underweight. Boys were found to have a higher risk of all three variables for malnutrition. In the absence of drought, with an increase in access to food and EVI, a lower risk of wasting and stunting was evident. In a multivariate analysis of EVI, the odds ratio (OR) for wasting was 0.66 (95% CrI: 0.45, 0.95), stunting 0.59 (95% CrI: 0.42, 0.82) and underweight 0.69 (95% CrI: 0.67, 0.72). In children >24 months, there was a decrease in the risk of wasting (OR=0.80, 95% CrI: 0.73–0.87) and risk of stunting (OR=1.76, 95% CrI: 1.61–1.91) and an increase in underweight (OR=1.99, 95% CrI: 1.84–2.16). There was a higher risk of wasting, stunting and underweight in children who had diarrhoea and acute respiratory infection. Vitamin A supplementation was only associated with a low risk of wasting.

<b>Author name(s):</b>	Kinyoki, DK, Moloney, GM, Uthman, OA, Kandala, NB, Odundo, EO, Noor, AM, Berkley, JA (2017)
<b>Article title:</b>	Conflict in Somalia: impact on child undernutrition.
<b>Methods:</b>	Surveys were conducted from 2007 to 2010 to assess the nutritional status of 73 778 children in Somalia. A multistage clustering sampling method was used to select participants and surveys were conducted biannually. Variables on child health, household factors and environmental measures were the same as a previous study conducted (Kinyoki et.al, 2016). An additional variable on conflict data was collected using Armed Conflict Location and Event Data (ACLED). Data on violent and non-violent crimes, from various sources, are captured in this database.
<b>Drought exposure:</b>	EVI was used as a proxy for rainfall and drought
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, instances of food insecurity are increased which could result in poor childhood outcomes. Conflict is thought to further negatively impact children's health.
<b>Health outcome(s) investigated:</b>	Wasting, underweight and stunting in children
<b>Additional findings reported</b>	Findings of this study on the effect of drought on wasting, underweight and stunting in children are the same as a previous study conducted in 2016 by Kinyoki et.al. The authors further assessed the effect of conflict on these three variables. In cases of recent conflict, the odds ratio (OR) for wasting was 1.37 (95% credible interval (CrI): (1.33, 1.42), the OR for stunting was found to be 1.21 (95% CrI (1.15, 1.28). In cases of long-term conflict, the OR for wasting was 1.76 (95% CrI (1.71, 1.81), and the OR for stunting was 1.88 (95% CrI (1.83, 1.94). This shows that long-term conflict has a greater effect on wasting and stunting in the presence of drought. After controlling for confounding factors, the odds of wasting and stunting in the presence of conflict were greater by 76% and 88% respectively. The attributable fraction for wasting was 13% and stunting was 14%.

<b>Author name(s):</b>	Belayneh, M, Loha, E, Lindtjorn, B (2019)
<b>Article title:</b>	Food Insecurity, Wasting and Stunting Among Young Children in a Drought Prone Area in South Ethiopia: A Cohort Study (P04-040-19).
<b>Methods:</b>	The study was conducted in the Boricha area in Ethiopia, which experienced chronic food insecurity. Data was collected in 2017 in two periods: pre-harvest (March-June) and post-harvest (September-December). Mother-child pairs (n=935), in 894 households, were studied.
<b>Drought exposure:</b>	Drought measurements were not done but the study was conducted in a drought-prone area.
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, instances of food insecurity are increased which could result in poor childhood outcomes.
<b>Health outcome(s) investigated:</b>	Wasting and stunting in children
<b>Additional findings reported</b>	From 894 households surveyed, 82% were found to experience food insecurity, based on self-reports (95% CI: 80.3–82.9). Food insecurity was highest in March (69%) as opposed to the post-harvest period (50% in September). The prevalence of stunting in the sample was 44% (95% CI: 42.3–45.6) and varies seasonally. Stunting occurred a few months after periods of food insecurity. Wasting prevalence in children was found to be 6% (95% CI:5.0–6.6), with a higher prevalence in poor and food-insecure households, children with recent illness and households with uneducated fathers.

<b>Author name(s):</b>	<b>Ardalan, A, Belay, GD, Assen, M, Attar, MJH, Khoei, EM, Ostadtaghizadeh, A (2019)</b>
<b>Article title:</b>	Impact of climate change on community health and resilience in Ethiopia: A review article
<b>Methods:</b>	Electronic databases searched included MEDLINE, EMBASE PubMed and Google Scholar and Scopus. The search was limited to English articles published between January 2004 and December 2018. The keywords used included “prevention” “Emergency disaster”, “recovery”, “response”, “preparedness”, “drought”, “food insecurity”, “coping strategies” and “drought health policy”. Articles were selected based on an inclusion criterion and were reviewed independently by authors.
<b>Drought exposure:</b>	N/A
<b>Relevance to HVI or drought outcome:</b>	In the context of drought, instances of food insecurity are increased which could result in poor childhood outcomes.
<b>Health outcome(s) investigated:</b>	Stunting, underweight and wasting
<b>Additional findings reported</b>	Twenty articles meeting the inclusion criteria were selected and included in the review. Studies were commonly conducted in Southern Ethiopia (40%) and 75% of included studies used a cross-sectional study design. Most of the studies were conducted in rural areas. The sampling techniques used included multi-stage (25%), two-stage (15%), systematic random sampling (15%) and systematic and purposive (5%) sampling techniques. The most relevant study findings were as follows: One study conducted in 2011 (n=614 households) found that 54.1% of households experienced food insecurity. The authors used a two-stage probability sampling technique, to administer community based cross-sectional surveys, in order to assess the percentage of households who reported food insecurity. In the same year, a separate study (n= 1094 households) found that moderate and severe hunger was 29% and 5.6% respectively. Two studies assessed the nutritional status of children in Ethiopia. The first study in 2005 (n=144 households) found the prevalence of stunting, underweight and wasting to be 44.5%, 25% and 9%. The second ecological study, conducted in 2014 found the prevalence of stunting, underweight and wasting to be 55.2%, 42.5% and 10.1%. A study conducted in 2015 (n=206 children) found that in school children, 11.6% of participants were underweight and 2% had a low BMI.



<b>Author name(s):</b>	<b>Delbiso, TD, Altare, C, Rodriguez-Llanes, JM, Doocy, S, Guha-Sapir, D (2017)</b>
<b>Article title:</b>	Drought and child mortality: a meta-analysis of small-scale surveys from Ethiopia.
<b>Methods:</b>	Data on the under-five death rate (U5DR) was extracted from the Complex Emergency Database (CE-DAT). Based on the inclusion criteria, 88 surveys, conducted between January 2009 and December 2014, were included in the analysis. The inclusion criteria for this study were (1) studies conducted on permanent residents, (2) surveys which used probability sampling in their methodology, (3) surveys which have a 3-month recall period and (4) surveys in which the U5DR and/or sample size were provided. From the 88 included surveys, the sample for the meta-analysis consisted of 55219 children under the age of five. The surveys covered 7 regions in Ethiopia. Drought exposure was measured using a Standardized Precipitation Evapotranspiration Index (SPEI). Short- and long-term drought was defined by calculation 3-month and 12- month SPEI's.
<b>Drought exposure:</b>	SPEI is a reliable index to measure drought exposure and intensity (Zargar et.al, 2011)
<b>Relevance to HVI or drought outcome:</b>	Drought has been associated with inducing nutritional and health-related problems which could, as a long-term effect, lead to an increase in mortality in children under the age of 5.
<b>Health outcome(s) investigated:</b>	U5DR
<b>Additional findings reported</b>	The short-term drought was reported in 56.8% of surveys and long-term drought in 67%, with 95.1% of surveys conducted in areas experiencing food insecurity. The study found that the pooled U5DR was 0.323/10,000/day (95% credible interval, CrI: 0.254–0.397). Heterogeneity of included survey estimates was $\tau^2 = 0.38$ (95% CrI: 0.17–0.71). Drought, both long- and short-term were not associated with U5DR. The U5DR was higher in surveys reporting minimal food insecurity compared to those surveys reporting intense food insecurity, 0.722 (95% CrI: 0.317–1.458) and 0.287 (95% CrI: 0.205–0.388). This result could be due to the presence humanitarian aid aimed at reducing child mortality, particularly in vulnerable populations. Other possible explanations for the lower U5DR include underreporting of child mortality, particularly in areas which are inaccessible due to security concerns, survival bias, early warning systems and greater adaptive capacity of the country by improving community resilience to long-term effects of food insecurities.

<b>Author name(s):</b>	<b>Gari, T, Loha, E, Deressa, W, Solomon, T, Atsbeha, H, Assegid, M, Hailu, A, Lindtjørn, B (2017)</b>
<b>Article title:</b>	Anaemia among children in a drought-affected community in south-central Ethiopia
<b>Methods:</b>	The study was conducted in the Oromia Regional State in Ethiopia, in 48 “kebels” (lowest government administrative unit). The region has experienced repeated episodes of drought since the 2015 and early 2016 El Nino event. This study was conducted as part of a randomized control field trial that investigated the effects of long-lasting insecticidal nets and indoor residual sprays on malaria prevention. The authors of this study measured the prevalence of anaemia by measuring haemoglobin levels and aimed to determine the risk factors for anaemia in children aged 6-59 months. Surveys were conducted in December 2014 and December 2015 on 2984 and 3128 children, respectively. In the December 2014 survey, two cohorts were enrolled. The first cohort consisted of non-anaemic children, whose main exposure was malaria, and the outcome tested for was malaria. This cohort was followed for a year. This was a dynamic cohort in which older children left the survey and newborns and newcomers were added. The second cohort was only those children who participated in the 2014 survey and in the 2015 survey. Structured questionnaires were used to collect socio-demographic and economic data. Haemoglobin, anthropometric and malaria measures were conducted by nurses. For malaria and haemoglobin measurements, blood samples were collected from finger-pricks. Diagnosis of anaemia was based on WHO guidelines i.e. levels <11g/dl. Anaemia was further categorized according to mild (10-10.9 g/dl), moderate (7-9.9 g/dl) and severe (<7 g/dl) anaemia. Anthropometric measurements for malnutrition included weight, height/length of children.
<b>Drought exposure:</b>	Drought variable was not measured directly. However, the 2015-2016 El Nino events caused severe drought in the region. The authors also collected data on annual rainfall from 2011-2015, which decreased from 673mm to 471mm.
<b>Relevance to HVI or drought outcome:</b>	In periods of drought and food insecurity, the prevalence of anaemia may be increased.
<b>Health outcome(s) investigated:</b>	Prevalence of anaemia in children
<b>Additional findings reported</b>	The mean age of children enrolled in the 2014 and 2015 survey was 33.6 and 35.2 months, respectively. The prevalence of anaemia increased from 2014 [28.2% (95% CI, 26.6±29.8)] to 2015 [36.8% (95% CI; 35.1±38.5)]. Mild and moderate anaemia also increased from 2014 to 2015. The incidence rate in the dynamic cohort, after the 1-year follow-up was 30 cases/100 children years of observation (95% CI, 28-32). The hazard ratio for anaemia for children having malaria was 10.4. Risk factors associated with anaemia included poor socioeconomic status, stunting, age <36 months and household head educational status. The prevalence of stunting increased between 2014 to 2015 from 44.8% to 50.7% (p<0.001). The prevalence of underweight decreased between 2014 to 2015 from 18.5% to 15.4%. Similarly, the prevalence of wasting decreased between 2014 to 2015 from 7.3% to 4.1%.

<b>Author name(s):</b>	<b>Dinkelman, T (2015)</b>
<b>Article title:</b>	Long-run health repercussions of drought shocks: evidence from South African homelands
<b>Methods:</b>	Data on disability, fertility and cohort size was taken from Census data. The sample consisted of participants born between 1948 and 1986, and those who live or lived in rural homelands. Census data does not include the district of birth. Therefore, to obtain information on the district, participants were asked “Where do you live now? Where did you live before this?” Drought was measured using rainfall data from South Africa, from 1000 local weather stations. Drought measures specific for district and year were constructed using the Standardized Precipitation Index (SPI).
<b>Drought exposure:</b>	SPI constructed from rainfall data
<b>Relevance to HVI or drought outcome:</b>	Previous studies have shown that prolonged exposure to drought, from the antenatal period to the age of four, increases the risk of disability in children.
<b>Health outcome(s) investigated:</b>	Prevalence of disability
<b>Additional findings reported</b>	The study found that 6.7% of participants experienced drought in the year of birth. The rate of disability, from exposure to drought in infancy, increases by 3.5% particularly for mental and physical disabilities. The total prevalence of disability in this sample was 5.2%. Visual, physical and speech or hearing disabilities accounted for 2.3%, 1.4% and 1.1%, respectively. A small percentage (0.7%) of participants reported mental disabilities. Estimates for disability were found to be higher in males, with a 5.2% increase in the probability of males reporting any disabilities. On an individual level, the probability of reporting any disability from drought exposure was found to be 0.186 percentage points.

## E.2. Drought and food consumption:

<b>Author name(s):</b>	Nichols EK, Talley LE, Birungi N, McClelland A, Madraa E, Chandia AB, Nivet J, Flores-Ayala R, Serdula MK. (2013)
<b>Article title:</b>	Suspected outbreak of riboflavin deficiency among populations reliant on food assistance: a case study of drought stricken Karamoja, Uganda, 2009-2010.
<b>Methods:</b>	179 172 participants (children and adults) underwent rapid assessment, and/or mass screening for AS in the Nakapiripit district in Uganda. Additionally, 76 participants were tested for riboflavin deficiency. The erythrocyte glutathione reductase activation coefficient (EGRac) was assessed to measure riboflavin levels. Food ration analysis was conducted using food planning and distribution records of an adjacent district. These measurements were used as a proxy for the study area of Nakapiripit
<b>Drought exposure:</b>	Drought exposure was not measured. However contextual information, regarding climatic shock and crop failure, from the Ministry of health, was used to frame the study.
<b>Relevance to HVI or drought outcome:</b>	Dietary consumption of food rations; do not meet required micro-nutrient levels
<b>Health outcome(s) investigated:</b>	Angular stomatitis (AS) due to riboflavin deficiency (RD)
<b>Additional findings reported</b>	0.2% (n=399) of participants showed signs of AS. 86.8% of those tested participants (n=78), were riboflavin deficient. Food ration analysis showed that only 55% of distributions met less than half of the required daily allowance (RDA) of riboflavin.

<b>Author name(s):</b>	<b>Ngudi DD, Kuo, Y, Van Montagu M, Lambein F (2012)</b>
<b>Article title:</b>	Research on motor neuron diseases konzo and neurolathyrism: trends from 1990 to 2010.
<b>Methods:</b>	Web of Science database searched using keywords; <i>konzo, neurolathyrism, HTLV-1 associated myelopathy/Tropical spastic paraparesis</i> . Pubmed database was also searched (Keywords not provided). The search was limited to 1990-2010. The study focused on the interest in 3 motor neuron diseases (i.e. konzo, neurolathyrism, HTLV-1 associated myelopathy/Tropical spastic) by comparing how many published articles their search revealed. Authors compare how many published articles their search revealed.
<b>Drought exposure:</b>	Drought exposure was not measured; however, the authors suggest that during and after periods of drought, reliance on grass pea seeds and cassava roots increased, particularly in rural areas. These drought-tolerant food sources are neurotoxic and can cause Konzo and neurolathyrism
<b>Relevance to HVI or drought outcome:</b>	Dietary consumption of drought-tolerant crop, grass pea seeds and cassava roots
<b>Health outcome(s) investigated:</b>	Konzo and neurolathyrism
<b>Additional findings reported:</b>	Results from Web of Science produced 84, 99 and 504 articles on Konzo, neurolathyrism and HAM/TSP respectively. This study found that there is no increase in the number of publications of the Konzo and neurolathyrism ( $R^2 = 0.006$ ; $P = 0.749$ and $R^2 = 0.045$ ; $P = 0.357$ , respectively) compared to HTLV-1/TSP ( $R^2 = 0.645$ ; $P, 0.05$ ). The results show that there is limited scientific interest in these motor neuron diseases. The authors suggest that there is a lack of government interest and funding for these diseases as they affect a small percentage of individuals in the population, who often reside in remote areas in India and Sub-Saharan Africa. Other reasons for diminished interest are that it is a non-infectious disease (compared to HTLV-1/TSP) and the belief that one is inflicted with the disease through witchcraft. The authors do not list the included studies from this review and the evidence found in those studies. Disease prevalence is also not discussed in the results of the study.

### E.3. Drought and water-borne, water-washed and water-related diseases:

<b>Author name(s):</b>	Rebaudet S, Sudre B, Faucher B, Piarroux R (2013)
<b>Article title:</b>	Environmental determinants of cholera outbreaks in inland Africa: a systematic review of main transmission foci and propagation routes.
<b>Methods:</b>	Pubmed and Promed-mail database searched using keywords; <i>“cholera OR Vibrio cholerae” and “Africa” OR the current or past names of all sub-Saharan African countries</i> . Search was limited to 1970- September 2012, and articles written in French or English. Grey literature was searched using Google and Google Scholar. Reference list of textbooks were also searched. Articles were screened independently by 2 reviewers. Inclusion criteria included information of cholera outbreaks or cholera related morbidity and specific to inland countries.
<b>Drought exposure:</b>	N/A
<b>Relevance to HVI or drought outcome:</b>	During periods of drought, where access to clean water is reduced, there is an increase in diarrhoeal diseases, including an increase in the incidence of cholera outbreaks. This study focuses more on the social and political drivers, such as war and forced migration, which increases the risk of cholera epidemics.
<b>Health outcome(s) investigated:</b>	Cholera outbreaks
<b>Additional findings reported</b>	In the past two decades, most cholera cases in Africa were reported around the African Great Lakes Region and the Lake Chad Basin. The African Great Lake region is reportedly overpopulated and has many refugee camps. In 1994, a huge refugee camp (approximately 500 000 to 800 000 people) close to Lake Kivu, experienced an outbreak of cholera with an estimated 50 000 cases of cholera. Spread of cholera in Africa has been attributed to movement along the main rivers, particularly in the region of Sahel. Authors also found that precipitation patterns influence cholera epidemics in Uganda, Zambia and Malawi. In Sahel, in the 1970’s and 1984–1986 cholera epidemics affected drought and famine-stricken areas. However, major outbreaks in the last 20 years have occurred during the rainy seasons, suggesting a complexity in the seasonality of cholera. A similar pattern of an increased cholera incidence in periods of both drought and excessive rainfall was seen in Niger. The association between drought and cholera outbreaks could also be exacerbated by social determinants, as seen in context of civil wars, which forces communities to reside in refugee camps and have limited access to safe drinking water.

<b>Author name(s):</b>	Rieckmann A, Tamason CC, Gurley ES, Rod NH, Jensen PKM (2018)
<b>Article title:</b>	Exploring Droughts and Floods and Their Association with Cholera Outbreaks in Sub-Saharan Africa: A Register-Based Ecological Study from 1990 to 2010.
<b>Methods:</b>	EM-DAT International Disaster Databases from 1990-2010 was used to extract data on cholera, droughts and floods. The case definition for cholera outbreak was the isolation of serogroups O1 or O139 from a single case. Additional case definitions were “acute diarrhoeal syndrome” and “acute watery diarrhoea” as there may be underreporting of cases. An analysis of 41 countries in Sub-Saharan Africa was conducted and the incidence rates for cholera was calculated for three different time periods: drought, floods and drought/flood-free periods.
<b>Drought exposure:</b>	EM-DAT: International Disaster Databases 1990-2010
<b>Relevance to HVI or drought outcome:</b>	During periods of drought, where access to clean water is reduced, there is an increase in diarrhoeal diseases, including an increase in the incidence of cholera outbreaks.
<b>Health outcome(s) investigated:</b>	Cholera outbreaks defined as “acute diarrhoeal syndrome” or “acute watery diarrhoea”
<b>Additional findings reported</b>	Droughts are linked to increased risk of diarrhoeal disease, including cholera, when there is a decrease in amount of water available for hygiene purposes. There is under reporting of cholera outbreaks due to lack of detection and political agendas to avoid negative economic impacts of reporting such outbreaks. Within the 21-year follow-up in the 41 countries, 276 cholera outbreaks were registered with 118 registered drought episodes, having a median length of 1.2 years. In cases where data on the start (8/118) or the ends (85/118) of drought periods were missing, researchers manually inputted this information. Twenty-five cholera outbreaks occurred during drought periods, 24 during flood periods, 10 during both drought and flood periods and the remainder (217) began during drought/flood-free periods. The number of outbreaks per drought periods was 4.5 times larger than the number per floods periods. The number of outbreaks per drought periods were 4.3 times larger than per drought/flood-free periods. Better preparedness for these outbreaks during periods of drought, may result in a lower disease incidence.

<b>Author name(s):</b>	Alexander KA, Carzolio M, Goodin D, Vance E (2013)
<b>Article title:</b>	Climate change is likely to worsen the public health threat of diarrhoeal disease in Botswana.
<b>Methods:</b>	Temperature and vapor data, as well as a climatic index for aridity, were extracted from the Climate Research Unit (CRU) TS 3.10, for a 30-year time period. Diarrhoeal case incidence data was extracted from annual reports, of diarrhoeal patients who presented to healthcare facilities, prepared by the Central Statistics Office. Classification of diarrhoeal disease was based on government identified disease categories (1974-1978) and the most recently revised International Classification of Disease (ICD) guidelines (1979-2009).
<b>Drought exposure:</b>	Climate data such as temperature measurements, rainfall and vapor pressure, for a 30-year period (1974-2003), was taken from the Climate Research Unit (CRU) TS 3.10 and used to measure wet and dry periods. A climatic index, which measures aridity, was also calculated and used in the analysis
<b>Relevance to HVI or drought outcome:</b>	Increase in diarrhoeal disease during dry periods possibly due to increase in fly population size and activity.
<b>Health outcome(s) investigated:</b>	Diarrhoeal disease
<b>Additional findings reported</b>	In the 30-year periods, the annual average rainfall was 36.97mm ± 44.15 mm, with monthly rainfall ranging from 0-254mm. Over 46% of the 30 years had at least one month with no rainfall. During dry seasons, compared to the wet season, there was an annual increase in diarrhoeal cases by 20%. This could be due to favourable climatic conditions, occurring during the dry seasons, which affect fly population density and thereby enhancing transmission of pathogens.



<b>Author name(s):</b>	<b>Bandyopadhyay, S, Kanji, S, Wang, L (2012)</b>
<b>Article title:</b>	The impact of rainfall and temperature variation on diarrhoeal prevalence in Sub-Saharan Africa
<b>Methods:</b>	Data was taken from the Demographic and Health Surveys (DHS) for Sub-Saharan Africa, in which a nationally representative sample was surveyed. Precipitation and temperature data were obtained from the Africa Rainfall and Temperature Evaluation System (ARTES). Survey information from 13 countries were obtained. The lagged variables for weather indicators (temperature and rainfall) were constructed against diarrhoeal disease prevalence.
<b>Drought exposure:</b>	Africa Rainfall and Temperature Evaluation Systems (ARTES)
<b>Relevance to HVI or drought outcome:</b>	Decreased rainfall in dry periods increases the prevalence of diarrhoeal diseases.
<b>Health outcome(s) investigated:</b>	Diarrhoeal diseases
<b>Additional findings reported</b>	The average diarrhoeal prevalence was 22.9%. During dry periods, when rainfall is decreased, the prevalence of diarrhoeal diseases increases in children under five. When rainfall is plentiful, there is a decrease in diarrhoeal diseases by approximately 3%. This is due to an increase in quantity and quality of safe drinking water, better hygiene practices and improved nutritional status, particularly in regions dependent on crops for sustenance. An increase in maximum temperature by 1 °C was found to increase diarrhoeal disease prevalence by 1%.

<b>Author name(s):</b>	Ahmed, SA, Flórez, MG, Karanis, P (2018)
<b>Article title:</b>	The impact of water crises and climate changes on the transmission of protozoan parasites in Africa
<b>Methods:</b>	Electronic databases were searched included Scopus, PubMed, Google Scholar, Web of Knowledge, African Journals online, Library Genesis Scientific Articles and Egyptian Knowledge Bank. Keywords used were ' <i>Balantidium coli</i> ', ' <i>Blastocystis hominis</i> ', ' <i>Cryptosporidium</i> ', ' <i>Cyclospora</i> ', ' <i>Dientamoeba fragilis</i> ', ' <i>Entamoeba</i> ', ' <i>free living amoebae, (FLA)</i> ', ' <i>Giardia</i> ', ' <i>Isospora belli</i> ', ' <i>Microsporidia</i> ', ' <i>Sarcocystis spp.</i> ' ' <i>Toxoplasma</i> ' AND ' <i>water</i> ', ' <i>climate</i> ', ' <i>crisis</i> ', ' <i>outbreak</i> ', ' <i>transmission</i> ', ' <i>incidence/prevalence</i> ' AND ' <i>Africa and list of African countries</i> '.
<b>Drought exposure:</b>	N/A
<b>Relevance to HVI or drought outcome:</b>	Episodes of drought decrease the quantity and quality of available water. Transmission of Waterborne protozoa (WBP) parasites increases in areas of poor access to water and poor sanitation.
<b>Health outcome(s) investigated:</b>	Waterborne protozoa (WBP) outbreaks
<b>Additional findings reported</b>	Climate extremes, such as drought, are expected to lead to water crises in Africa, that subsequently lead to WBP and foodborne outbreaks. From the 120 included studies, the highest number of reports was from Egypt (36), South Africa (13), Nigeria (11) and Tunisia (11). North Africa, compared to other regions in Africa, have the highest number of WBP reports. The presence of <i>Cryptosporidium</i> spp. and <i>G. duodenalis</i> was found in 12 and 16 African countries respectively. <i>Acanthamoeba</i> and <i>Naegleria</i> spp. (known as FLA) is the third leading cause of contamination, was documented in 40 of the included articles. <i>Entamoeba</i> spp. was reported by 10 African countries, including Ethiopia, Egypt and Sudan where the presence of <i>Entamoeba</i> spp. was found in drinking water. Reports on other WBP were scarce. Despite the reporting of WBP in water bodies in 21 African countries, there has been no report of outbreaks in Africa.

<b>Author name(s):</b>	Enbiale, W, Ayalew, A (2018)
<b>Article title:</b>	Investigation of a Scabies Outbreak in Drought-Affected Areas in Ethiopia.
<b>Methods:</b>	Data on scabies outbreaks was collected in two phases, with both phases being conducted during a drought period. In phase 1 (October to November 2015), house-to-house surveys were conducted by health care workers (HCW), in 68 districts in the Amhara region. All household members were screened, and demographic information was collected. Participants were divided into different age categories i.e. <2 years, 2 to 18 years, >18 years. In phase 2, (performed from October to December 2015), the aim was to validate the information collected by HCW and to further understand the underlying factors associated with the scabies epidemic.
<b>Drought exposure:</b>	The International Disaster Database. Ethiopia experienced extreme water shortages following the 2015-2016 El-Nino event.
<b>Relevance to HVI or drought outcome:</b>	Drought decreases access to clean water for hygiene and basic sanitation thereby increasing the risk of communicable diseases such as scabies.
<b>Health outcome(s) investigated:</b>	Scabies outbreaks
<b>Additional findings reported</b>	Phase 1: The house-to-house surveys screened 1,125,770 individuals, in which 379,000 confirmed scabies cases were found, with 60% of these cases occurring in participants >18 years of age. Over half of the cases (51.6%) were female. The odds ratio for children and young adults for developing scabies were 2.5 compared to adults. In the 68 districts the prevalence of scabies ranged from 2% to 67% with a median prevalence of 33.5 (IQR 19–48%). Phase 2: Sixty-seven percent of cases in this phase were male. A total of 39% of cases occurred in school age children with the median age of cases being 10 years. In cases, 75.1% had family members who were affected and 30% of cases had a secondary bacterial infection. In this study, 11% of cases had reported leaving school due to drought and scabies. The level of agreement between the HCW findings in phase 1 and results of phase 2 was 98.3%.

<b>Author name(s):</b>	Ramesh A, Kovats S, Haslam D, Schmidt E, Gilbert CE (2013)
<b>Article title:</b>	The impact of climatic risk factors on the prevalence, distribution, and severity of acute and chronic trachoma.
<b>Methods:</b>	Various databases were searched; CAB Abstracts, Embase, Global Health, Medline and Web of Science. Lead international agencies searched included World Health Organization (WHO), WHO Special Programme for Research and Training in Tropical Diseases (TDR); Intergovernmental Panel on Climate Change (IPCC); United Nations Children's Fund (UNICEF); UN-Habitat; The Carter Centre; the International Trachoma Initiative (ITI); Sightsavers; Helen Keller International; Fred Hollows Foundation; Christian Blind Mission. The inclusion criteria were studies which showed an association between climatic factors and trachoma. The study period was from January 1950 to 1 April 2012. Articles were screened and analysed by two reviewers. STROBE checklist for cross-sectional studies was used.
<b>Drought exposure:</b>	N/A
<b>Relevance to HVI or drought outcome:</b>	Climatic variability, such as a decrease in rainfall, could increase the risk of trachoma prevalence
<b>Health outcome(s) investigated:</b>	Trachoma
<b>Additional findings reported</b>	<p>A total of 1751 articles were retrieved, of which only eight met the inclusion criteria. The included studies were all cross-sectional and diagnosis of cases were based on the World Health Organization (WHO) guidelines. The African countries in which these studies were conducted include Ethiopia, Mali, Sudan, Tanzania and Burkina Faso. The quality of the studies ranged from moderate to low. Studies with moderate ratings were those which had elaborate methodology, detailed climatic exposure measurements and intricate analyses.</p> <p>Two studies conducted in Mali assessed the effects of temperature on prevalence of trachoma. One study found a decrease in the prevalence of trachoma with a decrease in the annual temperature, whilst the other study found the opposite association. One study conducted in Burkina Faso found a decrease in trachoma prevalence with an increase in temperature, finding that a 1 °C rise in temperature resulted in a 43% lower disease risk. In studies that used altitude as a proxy for temperature, the authors report having a low confidence in the study results due to residual confounders. Four studies investigated the effect of rainfall on trachoma, with only two studies having significant findings. A study in Sudan found that active trachoma was associated with long-term average rainfall, showing that a 100mm decrease in rainfall resulted in a 79% higher prevalence. A study in Mali showed a decrease in the number of rainfall days increased the risk of active trachoma in children (odds ratio 1.59, 95% CI 1.03–2.44).</p>

<b>Author name(s):</b>	Anyamba A, Small JL, Britch SC, Tucker CJ, Pak EW, Reynolds CA, Crutchfield J, Linthicum KJ (2014)
<b>Article title:</b>	Recent weather extremes and impacts on agricultural production and vector-borne disease outbreak patterns.
<b>Methods:</b>	Rainfall data was extracted from the Global Precipitation Climatology Project. Vegetation and temperature were measured using Normalized difference vegetation index (NDVI) and land surface temperature (LST) measurements, respectively. Vector-borne disease outbreak was monitored and evaluated using various health organization records such as World Organization for Animal Health, Program for Monitoring Emerging Diseases and US Centres for Disease Control and Prevention. Outbreaks of West Nile Virus, dengue, Murray Valley encephalitis, Rift Valley fever were mapped and contrasted with focal regions experiencing weather anomalies.
<b>Drought exposure:</b>	Global Precipitation Climatology Project for rainfall measurements for different time periods, in different regions.
<b>Relevance to HVI or drought outcome:</b>	Drought and flooding could lead to ecological shifts which could lead to the emergence or re-emergence of vector-borne diseases and other pathogens.
<b>Health outcome(s) investigated:</b>	Vector-borne disease outbreaks
<b>Additional findings reported</b>	Between December 2010-February 2011, East Africa experienced an episode of drought, defined by rainfall being 85% below normal. The land surface temperature was above normal (5–20 °C) and this persistent, above-normal temperature was associated with a large-scale dengue outbreak in the region. High temperatures, together with severe drought, increased the breeding of mosquitoes causing dengue fever, with outbreaks detected in Mogadishu, Kenya and Somalia. In Somalia, pasture and vegetation of sorghum, a dietary staple, decreased by more than 80%. The occurrence of famine in this region, coupled with disease outbreaks, placed additional strain on already vulnerable populations. In South Africa, an abundance of rainfall (43% higher than normal), from December 2010-February 2011, resulted in favorable conditions for maize production. However, it also created environmentally favorable conditions for mosquitoes. An increase in rainfall, coupled with a decrease in seasonal temperatures, resulted in an increase in mosquito density and infection with Rift Valley fever. Subsequently, a more extensive and widespread outbreak of Rift Valley Fever occurred in this region.

<b>Author name(s):</b>	Bakshi, B., Nawrotzki, R.J., Donato, J.R. and Lelis, L.S (2019)
<b>Article title:</b>	Exploring the link between climate variability and mortality in Sub-Saharan Africa
<b>Methods:</b>	The effects of climate on mortality were studied in three African countries i.e. Kenya, Mali and Malawi, from 2008 to 2009. The study used the TerraPop data extraction system, which combines census-data and area-level data, to obtain data for the study variables i.e. mortality and climate. Demographic information e.g. educational level, of individuals living in each household, was collected. Estimates for the prevalence of malaria and HIV were taken from the Malaria Atlas Project and demographic and health surveys (DHS), respectively. Households reported on the number of deaths in the past year, leading up to the census month. The climate research unit time-series data (CRU-TS) was used to obtain information on temperature and precipitation. For temperature, one standard deviation (SD) above the normal was classified as a heatwave and one SD below was classified as a “cold snap”. Drought was defined by precipitation below normal by one SD. The climate impact index used in the study was a combination of drought and heatwaves, which often occur jointly.
<b>Drought exposure:</b>	Climate impact index
<b>Relevance to HVI or drought outcome:</b>	Climate variability, such as drought occurrences, increased mortality rates, particularly in regions where the HIV/AIDS prevalence is high.
<b>Health outcome(s) investigated:</b>	Mortality rates
<b>Additional findings reported</b>	Multivariate analysis was performed to control for confounding of non-climatic factors on mortality. In Kenya, Mali and Malawi, log mortality rates increase with age, lack of access to high-quality energy, low educational levels of household members, in female lead households and in households where the head was unmarried. In Kenya and Malawi, HIV/AIDS and malaria rates were significantly associated with high mortality rates. For climatic variables, heatwaves were not associated with an increase in mortality rates in Kenya, Malawi and Mali. In Kenya only, cold snaps were associated with an increase in mortality (0.40, $p < 0.001$ ). Drought was associated with an increase in mortality in Malawi (0.08, $p < 0.01$ ). When using an interactive model, to account for epidemiological contextual influences, the study also found that, in Kenya only, there is no effect of drought on mortality rates in regions of low HIV/AIDS prevalence. The opposite relationship is observed for drought and malaria in Kenya. In areas with high rates of malaria infection, adverse climatic conditions decreased mortality. In Kenya only, during instances of drought, where malaria prevalence is low, mortality rates increased.

#### E.4. Drought and health behaviours:

<b>Author name(s):</b>	Heaney AK, Winter SJ (2016)
<b>Article title:</b>	Climate-driven migration: An exploratory case study of Maasai health perceptions and help-seeking behaviours.
<b>Methods:</b>	Qualitative interviews were conducted in matched migrant and non-migrant groups in the Maasai population in Tanzania. Participants were matched according to demographics and location i.e. 14 permanent residents from rural areas and 14 rural-to-urban migrants. Interviews were conducted during July-August 2013, in which participants were asked mainly open-ended questions regarding their perceptions of health and health seeking behaviours.
<b>Drought exposure:</b>	Drought outcome not measured. Drought association with migration was based on previous studies performed in the Maasai population, in which 81% of participants report drought as a primary reason for moving out of their villages.
<b>Relevance to HVI or drought outcome:</b>	Climatic factors such as drought forces individuals to migrate out of their homelands in order to survive the effects of drought.
<b>Health outcome(s) investigated:</b>	Health seeking behaviours and health perceptions
<b>Additional findings reported</b>	Participants defined mental health as an individual feeling happy and having low stress level. Physical health was defined as an individual who is energetic, strong, normal weight and not feeling sick. Perceptions of health differed between the two groups. Mental health was of greater importance in the migrant group and physical health was of more importance in the non-migrant group. Migrant participants attributed poor mental wellness to social and emotional distresses such as lack of social support, concern of their families at home, loneliness and hopelessness. Migrant females did not report feelings of loneliness as much as their male counterparts. Authors suggest that this is due to the sense of community the female migrants have and the freedom to travel back to their homes as many of them are self-employed. Despite the acknowledgement that mental health was a concern in the migrant group, participants only sought help for physical ailments such as chest pains, fever, cough and swelling. The same health seeking behaviour was observed in the non-migrant group. Access to western healthcare was not problematic in both groups but participants would visit healthcare facilities as a last option. Authors conclude that greater utilization of healthcare facilities, particularly for mental health issues, could greatly improve participants mental and physical wellness

<b>Author name(s):</b>	Low A.J, Frederix K, McCracken S, Manyau S, Gummerson E, Radin E, Davia S, Longwe H, Ahmed N, Parekh B, Findley S, Schwitters A (2019)
<b>Article title:</b>	Association between severe drought and HIV prevention and care behaviours in Lesotho: A population-based survey 2016-2017
<b>Methods:</b>	Surveys were conducted between November 2016 and May 2017 as part of the Lesotho Population-Based HIV Impact Assessment (LePHIA) project, in 418 areas, across 10 districts in Lesotho. 12887 individuals, between the ages of 15-59 years were randomly selected and interviewed. The head of the household's answered socioeconomic and demographic questions and consented to HIV testing.
<b>Drought exposure:</b>	Precipitation estimates from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) <sup>1</sup> data. Satellite imagery and weather station data is used to create gridded rainfall estimates to detect the presence of drought <sup>1</sup> . Drought defined as <15% of the average rainfall.
<b>Relevance to HVI or drought outcome:</b>	Drought
<b>Health outcome(s) investigated:</b>	HIV status using surveys and point-of-care (POC) tests.
<b>Additional findings reported</b>	8824 of the 9403 selected households completed an interview and 11 682 individuals consented and tested for HIV. Approximately 94% of urban and rural households were located in areas of drought. The study found that during periods of drought, females from urban areas were 5 times more likely to engage in selling sex, 3 times more likely to experience forced sex and in females in rural areas, condom use was reduced (OR 0.70, 95% CI 0.54–0.92, p= 0.01). The prevalence of HIV in urban and rural areas was 26.9% and 24.7%, respectively, with a higher prevalence in females in both areas. In young people, HIV was associated with intergenerational sex in the past year, recent migration and marital status. There was no association between drought and HIV in older individuals.

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<sup>1</sup>CHIRPS is a rainfall data set that combines satellite imagery with weather station data to provide a detailed record of rainfall patterns. In this study, two-year total rainfall amounts (from 2014 to 2016) were summed up to capture the impact of the El-Nino event, and compared to 2-year rainfall from 1981 to 2016. This data was then converted into percentiles which signifies dry and wet periods.



<b>Author name(s):</b>	<b>Kock L, Prost A (2017)</b>
<b>Article title:</b>	Family Planning and the Samburu: A Qualitative Study Exploring the Thoughts of Men on a Population Health and Environment Programme in Rural Kenya
<b>Methods:</b>	Population Health and Environment (PHE) is a development initiative which focuses on three components i.e. conservation of the environment, health and family planning needs. PHE aims to address issues around reproductive health, as rapid population growth is seen to have negative impacts on the environment and human health. The Samburu district in Kenya has the highest fertility rates and with approximately 50% of women experienced unmet family planning needs. From the Samburu population, 27 men were recruited, using quota sampling. Participants participated in semi-structured interviews and focus groups discussions regarding their views on the PHE family planning programs targeted at the Samburu population.
<b>Drought exposure:</b>	Drought exposure not measured. However, authors used literature to substantiate the presence of drought in Samburu such as <i>“Samburu County Government. Facts and Figures” (2016)</i>
<b>Relevance to HVI or drought outcome:</b>	Pastoral communities experience increased vulnerabilities to the impact of drought when the natural resources they depend on for livelihoods are compromised. Rapid population growth, particularly in periods of drought, becomes problematic when livestock and supporting environment cannot sustain these large families.
<b>Health outcome(s) investigated:</b>	Perception of family planning
<b>Additional findings reported</b>	All participants stated that they were entirely reliant on natural resources for their livelihood and acknowledged that for having smaller family sizes would be beneficial for the environment and subsequently for their survival. Eight of the nine elders (>45 years) expressed concern on how difficult it is to sustain a larger family, given the increased occurrence of drought periods. Participants acknowledged that a larger family size meant there would be a need for a larger herd of livestock. During periods of drought, livestock mortality is increased, and parents are unable to provide for their children, which ultimately increases the vulnerability of the family. While participants in the younger age groups (18-45 years) shared the same sentiment, the desire to have a larger family was still present in this group, with some participants intending not to adopt any method of family planning. This highlights the need for more male support for family planning initiatives, particularly in an environmental context which is vulnerable to the widespread impact of frequent droughts

## Appendix F: Request letter from the University of Cape Town Human Research Ethics Committee (HREC)



**UNIVERSITY OF CAPE TOWN**  
**Faculty of Health Sciences**  
**Human Research Ethics Committee**



Room E53-46 Old Main Building  
Groota Schuur Hospital  
Observatory 7925  
Telephone [021] 406 6626  
Email: [shuretta.thomas@uct.ac.za](mailto:shuretta.thomas@uct.ac.za)

Website: [www.health.uct.ac.za/fhs/research/humanethics/forms](http://www.health.uct.ac.za/fhs/research/humanethics/forms)

25 June 2019

**HREC REF: 425/2019**

**A/Prof A Dalvie**  
Public Health and Family Medicine  
Falmouth Building

Dear A/Prof Dalvie

**PROJECT TITLE: THE ADVERSE HEALTH EFFECTS ASSOCIATED WITH DROUGHT IN AFRICA: WORKING TOWARDS DEVELOPING A VULNERABILITY INDEX (Masters Candidate - T Asmail)**

Thank you for submitting your request to the Faculty of Health Sciences Human Research Ethics Committee.

The HREC note that the proposed study is a systematic review and meta-analysis.

As the systematic review involves published literature available through publicly accessible electronic databases, research ethics review and approval is not required.

This is in accordance with Section 1.1.8 of the Department of Health's Ethics In Health Research: Principles, Processes and Structures (South African Department of Health, 2015), which states: *"Research that relies exclusively on publicly available information or accessible through legislation or regulation usually need not undergo formal ethics review. This does not mean that ethical considerations are irrelevant to the research."*

The HREC recommend that researchers refer to the PRISMA website, for the PRISMA statement and checklist, to facilitate the reporting of systematic reviews and meta-analyses. For more information, please refer to <http://www.prisma-statement.org/>.

Further, fundamental ethical principles for health-related research should be considered in the objectives and methods of the systematic review. See, for example, the Declaration of Helsinki (Fortaleza, Brazil, 2013) and the Department of Health's Ethics In Health Research: Principles, Processes and Structures (South African Department of Health, 2015)

Yours sincerely

Signature Removed

**PROFESSOR M BLOCKMAN**  
**CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE**

## Appendix G: Instruction for authors

### **Science of the Total Environment**

Available at [http://www.elsevier.com/journals/science-of-the-total-environment/0048-](http://www.elsevier.com/journals/science-of-the-total-environment/0048-9697/guide-for-authors)

[9697/guide-for-authors](http://www.elsevier.com/journals/science-of-the-total-environment/0048-9697/guide-for-authors) [Accessed 10 June 2020]

### **Article structure**

#### *Manuscript Page Limit*

There is no restriction on the number of pages, but brevity of papers is greatly encouraged. The length of a paper should be commensurate with the scientific information being reported. In particular, the introductory material should be limited to a few paragraphs and results presented in figures should not be repeated in tables.

#### *Subdivision - numbered sections*

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

#### *Introduction*

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

#### *Material and methods*

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

#### *Theory/calculation*

A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

#### *Results*

Results should be clear and concise.

#### *Discussion*

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

#### *Conclusions*

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

### *Appendices*

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly, for tables and figures: Table A.1; Fig. A.1, etc.

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Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proofreading the article, etc.).

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Strunk Jr., W., White, E.B., 2000. *The Elements of Style*, fourth ed. Longman, New York.

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Mettam, G.R., Adams, L.B., 2009. How to prepare an electronic version of your article, in: Jones, B.S., Smith, R.Z. (Eds.), *Introduction to the Electronic Age*. E-Publishing Inc., New York, pp. 281–304.

Reference to a website:

Cancer Research UK, 1975. *Cancer statistics reports for the UK*.

<http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/> (accessed 13 March 2003).

Reference to a dataset:

[dataset] Oguro, M., Imahiro, S., Saito, S., Nakashizuka, T., 2015. Mortality data for Japanese oak wilt disease and surrounding forest compositions. *Mendeley Data*, v1.

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