The impact of climate change on child health in Malawi: a literature review with a focus on undernutrition, infectious diseases and air pollution

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Abstract

Introduction: Children in low-income countries are projected to suffer the most from climate change. How child health is impacted in low-income countries is a field that is not yet fully developed with most literature published on middle- and high-income countries. Malawi is increasingly suffering from climate change due to extreme weather events. The effects of climate change could possibly impact progress towards achievement of the Sustainable Development Goals. This thesis was written with the objective to discuss the main health effects of climate change on all children in Malawi. Due to large scope of this subject this thesis focusses on undernutrition, infectious diseases and air pollution.

Methodology: A literature review was performed using the conceptual framework published by Helldén et al. “Climate change and child health”. Results were organised corresponding to the framework in the following chapters: Climate change and Malawi, Direct and indirect effects, Increased risk of disease and Child health effects. If no information was found on Malawi, surrounding countries or the larger regions were used to discuss possible effects. The discussion was organised following the most impacted SDG’s namely 1 to 6.

Results: Malawi is impacted by increased extreme weather events (floods, droughts, storms) which cause 1) direct and indirect increases of morbidity (injuries, infectious diseases) and mortality (drowning, direct impacts) 2) increased food insecurity leading to increased chronic and acute undernutrition 3) decreased educational attainment 4) decreased access to health care and 5) crippling infrastructure damages leading to forced migration and impacts on government financing. Temperature is expected to increase with 1.6-2.0°C in 2050 and possibly 2.3-6.3°C in 2090. Rainfall is expected to be more variable meaning more dry spells and more high intensity rain with no impact on mean annual rainfall. This could increase 1) water stress through increase evaporation 2) reduce crop yields leading to increases in undernutrition 3) affect education outcomes through increased ambient temperatures 4) increase air pollution by ozone and particulate matter leading to respiratory disease and possibly adverse perinatal outcomes 5) increased exposure to infectious diseases through changing vector patterns for malaria and possibly schistosomiasis and increased exposure to water borne diseases.

Discussion: Malawi is currently not on a trajectory to achieve SDG goal 1 (eliminate poverty) and SDG 2 (reduce stunting) in which climate change plays a considerable role. Progress on the targets for U5MR (3.2.1.), ending the malaria epidemic (3.3.3.), mortality due to air pollution and unsafe WASH circumstances (targets 3.9.1 and 3.9.2), educational attainment (target 4.1 and 4.2), eliminate gender based violence and access to sexual and reproductive health services (target 5.2 and 5.6) could be severely compromised by the effects of climate change. There is a considerable knowledge gap on the effects of heatwaves, air pollution, impact on inland lakes and fish stocks/pollution which needs to be addressed.

Recommendations: to Ministry of Health to address the knowledge gaps needed to make effective adaptation policies, to the revising committee of the NDC’s to use these results for making the NDC more child sensitive, to the revising committee of the National Resilience Strategy consider expanding child targeted policies, to the Dutch societies of health professionals, use advocacy to strive for effective climate change mitigation steps.

Key words: Climate change, child health, Malawi, SDG

Word count: 13192

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Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
AR	Assessment Report
ARV	Antiretroviral therapy (for HIV)
CCRA	Climate Change Risk Assessment
CCRI	Children's Climate Risk Index
CO2	Carbon dioxide
COP	Conference of the Parties to the Convention
COVID	Corona-Virus Disease
DALY	Disability adjusted life year
DD	Decimal Degrees
EWE	Extreme weather events
GDP	Gross Domestic Product
GNI	Gross National Income
HIPC	Highly Indebted Poor Countries
HIV	Human Immunodeficiency Virus
IMF	International Monetary Fund
IPCC	International Panel on Climate Change
LBW	Low Birth Weight
LDC	Least Developed Country
LIC	Low Income Country
MAM	Moderate Acute Malnutrition
MICS	Multiple Indicator Cluster Survey
NAPA	National Adaptation Plan for Action
NDC	Nationally Determined Contribution
PLWHA	People Living With HIV/AIDS
PM 2.5	Particulate Matter smaller than 2.5µm
PM 10	Particulate Matter smaller than 10µm
PMTCT	Prevention of Mother to Child transmission of HIV
PTB	Preterm Birth
RCP	Representative Concentration Pathway
SAM	Severe Acute Malnutrition
SDG	Sustainable Development Goal
SFP	Supplementary Feeding Programs
SGA	Small for Gestational Age
UN	United Nations
U5MR	Under 5 Mortality Rate
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USD	United States Dollar
WASH	Water, Sanitation and Hygiene
WG	Working Group
WHO	World Health Organization

Definition of terms:

Child: every human being below the age of eighteen years unless under the law applicable to the child, majority is attained earlier (1).

Climate: The classical period for averaging the mean and variability of relevant quantities such as temperature, precipitation and wind is 30 years, as defined by the World Meteorological Organisation (2).

Climate change: global warming by increased atmospheric concentrations of greenhouse gases due to human activity, mainly due to burning of fossil fuel and the conversion of natural habitat to land used for agriculture and human settlement (3). The first assessment report of the Intergovernmental Panel on Climate Change (IPCC), which was published in 1990, stated: “We are certain emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases” (4). This is reiterated in one of the latest IPCC reports in 2021: “it is unequivocal that human influence has warmed the atmosphere, ocean and land” (5). In the same report it is stated that the global average surface temperature was already 0.99 degrees Celsius higher in the past two decades compared to the years 1850-1900. In 2022 the IPCC WG2 stated: “Human induced climate change, …, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability” (6). Climate change is one of the nine planetary boundaries according to the planetary boundaries framework published by Rockström et al., with the boundary defined as 450 ppm CO2 in the atmosphere (7).

Climate change mitigation: a human intervention to reduce the sources or enhance the sinks of greenhouse gases (8).

Climate change adaptation in human systems: the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (9).

Climate justice: The term climate justice, while used in different ways in different contexts by different communities, generally includes three principles: distributive justice which refers to the allocation of burdens and benefits among individuals, nations and generations; procedural justice which refers to who decides and participates in decision-making; and recognition which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives (6). It takes into account the disbalance between the historical emissions by countries and the future negative consequences of climate change (10,11).

Evapotranspiration: evaporation from water surface areas and soil, including transpiration from plants (12)

Health: a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (13).

Health system: all organizations, people and actions whose primary intent is to promote, restore or maintain health (14).

Malnutrition: Weight for height > +2 (overweight) or < -2 SD (wasting) from the median of the World Health Organization (WHO) Child Growth Standards among children under 5 years (15).

Moderate acute malnutrition (MAM): weight for height between -3 and -2 z-score of the median of the WHO Child Growth Standards without oedema (16)

Natural resources: agriculture, fishery, forestry, mining, water, wildlife, biodiversity (17)

Planetary health: “the achievement of the highest attainable standard of health, wellbeing, and equity worldwide through judicious attention to the human systems—political, economic, and social—that shape the future of humanity and the Earth's natural systems that define the safe environmental limits within which humanity can flourish” (3).

Resilience: the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure (9).

Severe acute malnutrition (SAM): children aged 6-59 months who have weight for height < -3 z-score of the median of the WHO Child Growth Standards, or clinical signs of bilateral oedema of nutritional origin, or who have a mid-upper arm circumference < 115 mm (18)

Stunting: height for age < -2 SD from the median of the WHO Child Growth Standards among children under 5 years (15).

Sustainability: “Involves ensuring the persistence of natural and human systems, implying the continuous functioning of ecosystems, the conservation of high biodiversity, the recycling of natural resources and, in the human sector, successful application of justice and equity” (9).

Sustainable development: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (19).

Sustainable Development Goals (SDG’s): resolution adopted by the General Assembly of the United Nations on 21 October 2015 (A/RES/70/1) with the goal of transforming our world by creating an agenda for sustainable development in 17 goals and 169 targets (20).

Undernutrition: childhood undernutrition includes fetal growth restriction, stunting, wasting, underweight and deficiencies of vitamins and minerals (21).

Water security: “The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability” (22).

Background

Climate change and global health

In 2009 a commission of the Lancet and the Institute for Global Health at the University College London stated that climate change is the biggest threat to global health of the 21st century (23). Climate change has been on the global agenda for quite some years. The first "World Climate Conference" was organised in 1979 in Geneva (24) and the IPCC was established in 1988 (25). In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) agreement was signed, in which the signing countries recognized the threat of climate change and decided to protect the climate for present and future generations (26). In this agreement it was determined that ongoing evidence and policies should be regularly discussed during the Conference of the Parties to the Convention (COP), the first COP (COP1) was organized in 1995. Global awareness of climate change has been increasing in the past decades, but the strong link with global health is more recent. In 2001 the conclusion in the Third Assessment Report (TAR) of the Working Group 2 (WGII) from the IPCC was: "It will remain difficult in the near future to identify any early impacts of the current climate trends on health" (27). In the WHO report "Preventing disease through healthy environments" published in 2016 it is stated that 12.6 million global deaths annually (22.7% of total deaths) are attributable to the environment, which is impacted in many ways by climate change (28). Emerging infectious diseases are estimated to be more frequently occurring due to climate change (29,30) but the death toll of the COVID-19 pandemic, estimated to be 18.2 million by 31 December 2021 (31) will likely not be attributed to climate change since there is no direct evidence of a connection to the emergence of the disease (32).

Climate change and global child health

The worrying effects of climate change on child health were reported in the first review on this subject by Bunyavanich et al. in 2003 (30). This was confirmed in a report by the WHO in 2004 addressing the burden of disease attributable to climate change, with most deaths (151,000 out of 166,000) occurring in poor regions due to malnutrition, diarrhoea and malaria (33). The most recent assessment study by WHO published in 2014, the Climate Change Risk Assessment (CCRA), has tried to estimate the burden of disease in 2030 attributable to climate change of undernutrition, malaria, dengue, diarrheal disease and heat stress (34). In this assessment it is reported that millions additional children will be stunted and the annual mortality due to above mentioned causes was estimated to be almost 250,000 in 2030 and 84% of these deaths will be due to undernutrition, malaria and diarrhoeal disease, mostly occurring in low-resource countries (34). In the recent publication by UNICEF in 2021 "The climate crisis is a child rights crisis" it is stated that millions of children are highly exposed to climate and environmental hazards, shocks and stresses: 820 million children to heat waves, 400 million to tropical cyclones, 570 million to flooding, 920 million to water scarcity, 600 million to vector borne diseases, 815 million to lead pollution and 2 billion to air pollution (35). Due to these exposures children risk being caught in a vicious circle of increasing vulnerability (figure 1, annex 1) (35). In this publication the Children's Climate Risk Index (CCRI) is presented (figure 2, annex 1), which combines these exposures with pre-existing child vulnerabilities to identify countries where children are most at risk of climate change and hereby demonstrating how climate and environmental hazards are impacting ecosystems, resilience and child health (35). In the preparation for the COP26 in 2021 the Royal College of Paediatrics and Child Health (RCPCH) published a position paper urging global leaders to put child health central in all climate change policy decisions, deliver a rapid and just transition away from fossil fuels and to make targeted investments in climate-resilient, low-carbon and sustainable health and education services (36).

The first 1000 days

The importance of nutrition in early life is demonstrated by the fact that almost all stunting takes place in the first 1000 days after conception (37). Stunting is an important marker for chronic or recurrent undernutrition, it is defined by a reduced height-for-age z-score (HAZ-score) which prevents children from reaching their physical and cognitive potential (38). In the CCRA-study it is estimated that an additional 3.6 million children will be moderately stunted and 3.9 million will be severely stunted in 2030 due to the effects of climate change (34). Barker hypothesized that undernutrition in early life could explain why people from poor socio-economic groups in areas with high infant mortality have an increased risk of ischemic heart disease in later life (39), and Brenner hypothesised that the amount of nephrons you are born with determines your risk of hypertension later in life (40). This became later known as the Fetal Origin of Adult Disease hypothesis (FOAD) for which later studies found confirming evidence (41–43). An illustrative example is from the Dutch famine (hongerwinter) studies that found children who were born during the famine of 1944 having higher risks of glucose intolerance, coronary heart disease, obesity (women only) and obstructive airway disease later in life (42). Global organisations have taken up the call for improving nutrition in the first 1000 days (starting from conception), emphasising preconception counselling and nurturing care (44,45).

The Republic of Malawi

The Republic of Malawi, henceforth referred to as Malawi, is a landlocked country that relies greatly on agriculture for its income. It is located in the East African Rift Valley and shares a border with Tanzania to the north, Lake Malawi (Nyasa/Niassa) to the east, Mozambique to the south and Zambia to the west, coordinates are latitude 13.279956º S and longitude 34.294553º E in Decimal Degrees (DD) (46,47). Malawi gained independence from British colonial rule in 1964 (48). It has been classified up until now as a Least Developed Country (LDC) and a low income country (LIC) by the United Nations (UN) and the World Bank (49,50) The gross national income (GNI) per capita was 580 USD / year in 2020 according to the World Bank (51). The gross domestic product (GDP) was 12.63 billion in 2021, in current USD (52). The majority of employed people (73%) are working in the primary sector (agriculture, natural resources, mining and fisheries industries) (53). General information from the government website is shown in table 1.

Table 1: Country information: The Republic of Malawi

Land area	118 484 km^2 (20% water)
Population	18.6 million
Capital city	Lilongwe
Main towns	Blantyre, Zomba, Mzuzu
Climate	Tropical (cooler in highlands)
Official language	English
Common language	Chichewa
Currency	Kwacha
President	Dr. Lazarus McCarthy Chakwera
Government Ministries	21

Source: https://www.malawi.gov.mw, accessed 25-05-2022 (54)

Malawi has faced rapid population growth and a steadily increasing population density (55), as shown in table 2, next page. This has put increasing pressure and stress on the environment and on the country's natural resource base (ibid). The urban population has increased from 10.7% in 1987 to 15.3% in 2008 (17). Due to a declining fertility rate, which is still high (4.4 in 2015-16), the population of children under 5 years is expected to grow with 1.8 million this century, peaking at 4.6 million, and the proportion of children under 15 years is expected to grow with another 6.2 million this century, peaking at 13.78 million (48,56).

Especially noteworthy in the context of child health is the median age of 16.5 years in 2018 (55).

Table 2: UN Population Prospects 2019 Malawi

	Total population *in millions*	Under 5 years *in millions*	Under 15 years *in millions*
1950 (estimation)	3.0	0.6	1.3 (46% of total)
1990 (estimation)	9.4	1.7	4.2 (45% of total)
1992 (estimation)	9.7	1.8	4.4 (45% of total)
2015 (estimation)	16.7	2.8	7.6 (45% of total)
2030 (projection)	24.8	3.5	9.6 (39% of total)
2050 (projection)	38.1	4.3	12.3 (32% of total)
2100 (projection)	66.6	4.3 (peak 4.6 in 2072)	13.2 (peak 13.8 in 2077)

Source: World Population Prospects 2019 (56)

Malawi's health system and general economic situation

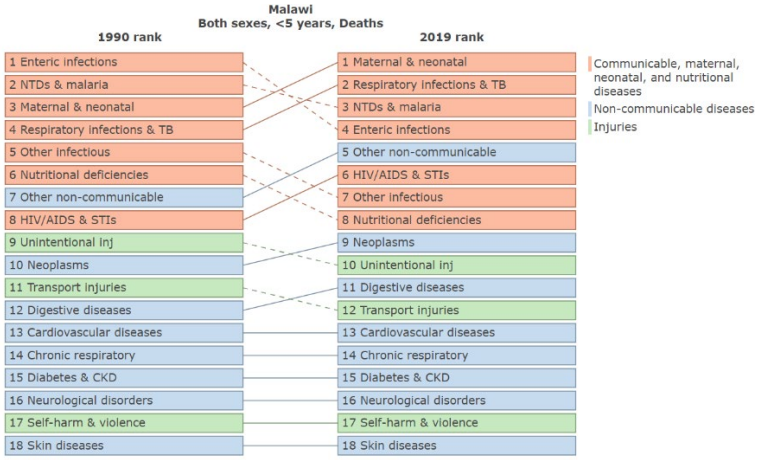
General information on the health system of Malawi is described in annex 3 and general information on the general economic situation of Malawi is described in annex 4.

Malawi and Child health

Malawi has made impressive progress in reducing the under-5 mortality rate (U5MR) from an estimated mortality rate of 247 deaths / 1000 livebirths in 1990 to 71 /1000 in 2013, a reduction of 71.3% (57). For this accomplishment it was selected to serve as an example case study by "Countdown to 2015" (57). Because of this progress it reached the goal two years prior to 2015, the target year set in Millennium Development Goal (MDG) 4: reducing U5MR by two-thirds (58). Malawi is also well on track for reaching the target set in SDG 3.2 for reducing the U5MR to below 25/1000 livebirths with a U5MR of 39/1000 in 2020 (20,59). When looking at stunting the decrease is more nuanced, the percentage of children under five who are stunted has decreased from 55% in 1992 to 37.4% in 2015 (60,61), the absolute number of stunted children has slightly increased from 990,188 to 1,027,514 (56,62). The intermediate goal for SDG 2.2 is to reduce stunting by 40% in 2025 compared to 2012. Stunting prevalence in 2012 was 44%, a 40% reduction would make the target for 2025 26.3% (63–65). In the previously mentioned UNICEF report, Malawi is taking the 40th place in the CCRI out of a total of 163 countries, where one is the country where children are most at risk from environmental and climate shocks (35).

Communicable diseases still play a major role in the under 5 mortality as shown in figure 3, next page. In a large study from 2019 on inpatient pediatric deaths in a tertiary government hospital the mortality rate was 3.5% (488/13,827). The leading cause of deaths were: sepsis (n=102, 20.9%), lower respiratory tract infection (LRTI) (n=67, 13.7%), acute gastro-enteritis (n=51, 10.5%), malaria (n=37, 7.6%) and meningitis (n=34, 7%) (66). Of the children who died, 37% were HIV infected or exposed and 21.7% had evidence of Severe Acute Malnutrition (SAM), for those with information available on these parameters (66).

Figure 3: Cause of under 5 deaths 1990 vs 2019 Malawi, both sexes (67)



Source: IHME Global Burden of Disease 2019 (67)
For a detailed account on cause of child deaths in Malawi see table 3, annex 2 (37).

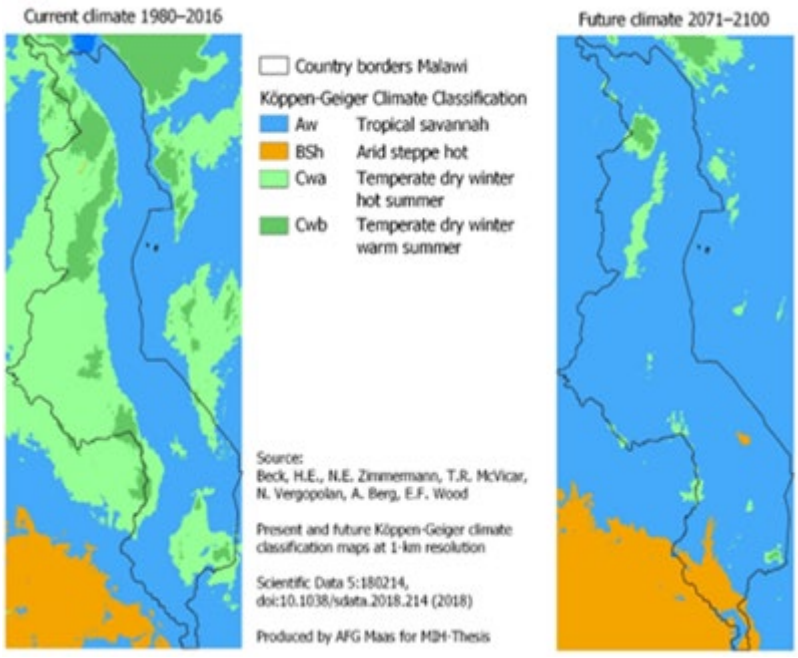
Malawi and Climate Change

Malawi is vulnerable to floods, droughts, hailstorms, strong winds associated with tropical cyclones and earthquakes, this is due to several geo-climatic factors (68,69). The climate in Malawi is influenced by the Intertropical Convergence Zone (ITCZ) and the El Niño Southern Oscillation (ENSO) (55) which occurs periodically every 2-7 years, the last one occurring in 2015-2016 followed by a season of severe floodings and droughts (70). A detailed description of the general climate of Malawi was recently published in 2021 by the Climate Centre of the Red Cross Red Crescent (71). Generally 95% of annual rainfall takes place during the summer rainy season which stretches from November until April (72).

Although floods and droughts and other shocks are common in many regions of Malawi (73) (see figures 4-5 in annex 1), the weather related shocks will likely increase in frequency and severity due to climate change (60,69). For the AR5 IPCC report in 2014 four scenarios were developed called the Representative Concentration Pathways (RCPs), each representing different emission levels and mitigation strategies and corresponding to different degrees of global warming (see figure 6 in annex 1) (74).

The climate of Malawi is expected to change according to figure 7 under the RCP 8.5 scenario based on data published in 2018 (75). This RCP 8.5 scenario is the best match until mid-century under current and stated policies (76). The consequences of these possible changes are yet to be determined.

Figure 7: Current and future climate Malawi



Policies on climate change

Global policies

In 2015 at the COP21 the landmark Paris agreement was adopted with its goal: “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels” (77). The Paris agreement requires the parties to prepare, communicate and maintain successive Nationally Determined Contributions (NDC’s) with mitigation measures that they intend to achieve (77). The amount of carbon emissions the world can “permit” to achieve the above goals is tracked by a “carbon budget”, to limit global warming for a 50% likelyhood to 1.5°C the remaining budget has shrunk to 120 GtC (420 GtCO2) equivalent to 11 years from the beginning of 2022, assuming 2021 emission levels (78), in another way visualised in figure 8 in annex 1. To assist countries in making vulnerability and adaptation assessments, the WHO has published the report “Protecting Health from Climate Change in 2013 (79). In 2018, African health and environment ministers re-endorsed the 10 years old Libreville Declaration on Health and Environment in Africa, signed by Malawi in 2008 (80).

National policies

Malawi was supported by WHO in conducting a vulnerability and adaptation assessment of the health sector to impacts of climate change in 2015 (80,81) and published National Adaptation Plans for Action (NAPAs) in 2006 (82) and 2015 (83) and a NAP-framework in 2020 (84). In June 2016 the Environmental Affairs Department of the Ministry of Natural Resources, Energy and Mining (EAD MoNREM) published the National Climate Change Management Policy (85). In this policy document priority areas are identified, policy goals are communicated and a.o. the roles and responsibilities of all stakeholders are presented, children are identified as a vulnerable group having special needs which need consideration (85). Since 2019 seven public health advisories on extreme weather events (EWE) were developed and are disseminated accordingly requesting communities to follow public health safety measures, additionally, the Health and Climate Change Core Team (HCCCT), comprised of various government sectors and partners, was instituted in order to provide an oversight and guidance on the implementation of health and climate change in the country (80).

In the updated version (2021) of the NDC that Malawi submitted to the NDC-Registry to the UNFCCC (86), it is mentioned that in 2017 the total annual greenhouse gas (GHG) emissions were 9 million tCO2e and it is expected to increase to 34 million tCO2e in 2040 in a business as usual situation (68). Total annual fossil CO2 emissions were 1.4 million tons in 2020 and the estimated total cumulative fossil CO2-emissions since 1751 were 50.7 million ton (87). For comparison, the total GHG emissions by the Netherlands, a high income country with about the same population, were 180.3 million tCO2e in 2019 having a decreasing trend (88). The annual fossil CO2 emission were 138.1 million tons in 2020 and the estimated total cumulative fossil CO2 emissions since 1751 were 11.74 billion ton (87).

From a climate justice perspective it is clear that the contribution of Malawi to climate change is very limited (89,90). So the role for Malawi in climate change mitigation (reduction of CO2-emissions) is limited compared to high-income countries. In the most recent NDC from Malawi, published in July 2021, ten strategic adaptation (dealing with the consequences of climate change) options are presented which include capacity building on Water, Sanitation and Hygiene (WASH) interventions and capacity building on diagnosis, prevention and control of climate-sensitive diseases and malnutrition (68). In a recent evaluation of NDC’s by UNICEF, Malawi is not identified as having a child-sensitive NDC (91).


The Spectator: 18 July 2022

Brendan O'Neill

The heatwave green hysteria is out of control

Everyone needs to calm down. We're safer from weather than we have ever been. It's sunny. Go outside. Sit in the shade. Have an ice-cream.

Problem statement and justification

Climate change denial, downplaying the effects of climate change and preventing effective policies on this subject is big business. In 2019 the Corporate Europe Observatory calculated that the biggest five oil and gas companies spend more than €250 million in lobbying the EU and saw hundreds of fossil fuel lobbyist attending the COP26 (92,93). During record breaking heatwaves this summer in Europe, downplaying the effects of climate change is also loud and clear as shown in the above headline (94).

This is unfortunately nothing new. In response to the forming of the IPCC also the Global Climate Coalition was formed, an industrial lobby group that has spent decades casting doubt on the scientific processes and outright denying the scientific consensus at that time, despite major oil companies already knowing about the effects of carbon emissions on global climate (95–98). It was already back in 1985 that the legendary science communicator Carl Sagan testified before the United States Congress about how the greenhouse effect works and the consequences of unlimited burning of fossil fuels (99).

Despite the Paris agreement, global CO2 emissions from fossil fuels have continued to rise until 2019, with a temporary small reduction in 2020 due to the coronavirus disease 2019 (COVID-19) pandemic (100).

The narrative of the limited effects of climate change on industrialized countries, like shown in the Spectator headline, is short-sighted and reduces the chance of effective climate change mitigation strategies from high emitting industrialized countries. The inequalities in carbon emissions are staggering: from 1990 until 2015 it was estimated that the consumption of the world's richest 1% drove twice as much carbon emissions as the poorest half of the world

combined and the richest 10% of the globe has been responsible for more than half of global carbon emissions (11). National navel gazing led to the withdrawal of the United States of America from the Paris agreement in November 2020 by promoting jobs and beautiful clean coal, see figure 10 (next page) (101). While at the other side of the Atlantic the European parliament decided that natural gas is “climate friendly, sustainable and green” (102) and one of the vice presidents of the European Commission doubting the commitment of youth climate activists accusing them of having “the Greta syndrome” by demonstrating but perhaps not being willing to pay the price of measures against climate change (103).

Figure 10: Trump ending the war on beautiful clean coal

Source: CNN, Dominick Reuter / AFP / Getty Images (101)

Low income countries are already suffering the consequences of climate change as stated before (104). Due to climate change millions of children will be undernourished and have an increased risk of dying (34). An additional annual 95,000 under five child deaths will occur due to undernutrition, 60,000 total deaths due to malaria (many of which will be children) and 48,000 deaths in children under 15 due to diarrhoeal disease (ibid). These deaths will occur in Sub-Sahara Africa for 70%, 95.6% and 63.5% respectively (ibid). Main limitations of this study were stated to be the inability to account for effects of economic damage due to major heatwave events, river flooding, water scarcity, effects on human security and the limited scope of the impacts that can be confidently modelled (ibid).

To which degree low-income countries are already suffering from climate change is an active field of research. This study is performed to take the perspective of children, the most vulnerable group in society, and to determine the health effects of climate change on them, specifically in a low-income country like Malawi. Although some country level assessments have been made by the Red Cross Red Crescent Climate Centre on climate change and health (105), specific focus on children is not common. An assessment of NAPA’s in 2017 showed that child health is hardly mentioned and is not adequately included in national adaptation measures or actions (106). In an analysis by UNICEF in 2021 only 35 out of the 103 analysed NDC’s were child sensitive, Malawi not being one of them (91). This thesis will discuss the literature on this topic so far and due to the broad scope of the impact of climate change, it will focus on infectious diseases, undernutrition and air pollution.

Objectives

Main objective

To discuss the main health effects of climate change on all children in Malawi focussing on undernutrition, infectious diseases and air pollution

Subobjectives

1. To explain how climate change affects and will further affect Malawi
2. To discuss how direct and indirect effects of climate change affect the risk of infectious diseases, undernutrition and respiratory diseases for children in Malawi
3. To identify child health related indicators within the SDG framework that are affected by climate change which can potentially reduce progress
4. To provide recommendations to the Malawi government and its partners about priority areas for adaptation and improving child health in light of climate change

Methods and analytical framework

To address the main objective of this thesis a literature review was conducted to gather information in a systematic way by using an analytical framework that addresses child health in relation to climate change.

Selection of analytical framework

The analytical framework was selected by performing a search in PubMed using the search terms: “framework, child health, climate change”. With this search 50 papers were found (exact search terms used in table 7, annex 2). The paper which was selected as best match (algoritm based) was that by Helldén et al, it presents an expanded conceptual framework on climate change and child health (12), figure 11. In the corresponding paper a scoping review was conducted from January 2000 to June 2019 on the impact of climate change on child health, existing conceptual frameworks where expanded into the one that was presented. The other 49 articles where screened for relevance but no other papers involved a framework about “child health” in general in relation to “climate change” in general. Since the review only included articles up until 06-2019 and did not target a specific country an additional search in PubMed was conducted to see whether adjustments or additions to the selected framework were necessary or justified. The search terms: “Malawi, child health, climate change”, with and without “framework” resulted in 0 and 3 articles respectively, limited from 06-2019 until 01-01-2022. The found articles did not provide additional topics or insights that justified changing the framework (exact search terms table 8, annex 2).

There have been several frameworks published about “health” and “climate change”. The advantage of the chosen framework over those, is that it includes both important aspects that relate ecosystem and environment change to human health (3) (figure 12 in annex 1) and relate climate change to health (107) (figure 13 in annex 1). The importance of this to child health is demonstrated by linking both ecosystem / environment disruption as an indirect effect and climate change as a direct effect to increased risk of disease by increasing the vulnerability of children due to food insecurity, reduced educational attainment, forced migration and exposure to toxicants in- and exutero. The disadvantage of this framework is that is does not take into account the effect of climate change on the five different types of household capital as described in the sustainable livelihoods framework (108) (see figure 14 in annex 1) which will be addressed in the discussion.

Figure 11: Climate change and child health: an expanded conceptual framework (12)

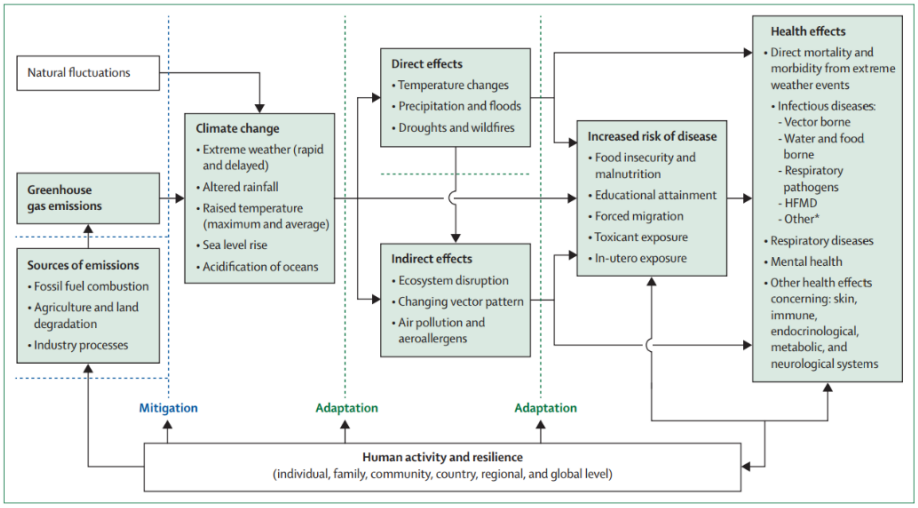


Figure 3: **Climate change and child health: an expanded framework**
The dashed lines show where mitigation and adaptation can hinder the effects of climate change on child health and wellbeing. HFMD=Hand, foot, and mouth disease. *Other infectious diseases, from mumps to bacterial meningitis, varicella viruses, and parasitic diseases.

** for a larger version of the framework see figure 11, annex 1*

Search Strategy

Key words were extracted from the analytical framework. The search terms that were used and how they were combined are presented in table 9, annex 2, organised per chapter. If for Malawi insufficient or no results were found, the search was expanded to the neighbouring countries Tanzania, Zambia and Mozambique or the greater region Southern Africa or Southern African Development Community (SADC) (109), Eastern Africa (110) or Sub-Sahara Africa (110). No time limit was initially placed on publication date.

The following online databases were searched: PubMed, Web of Science, Cochrane Library, IRIS (digital library of WHO), The World Bank, Google Scholar, WHO regional website for Africa, Scopus and LibSearch of the Free University of Amsterdam (a.o. CINAHL, ERIC, WorldCat, ScienceDirect, PsychINFO, Pubmed Central, BioMed Central). In addition to the databases above white papers and grey literature about climate change and Malawi published by UN organisations (UNICEF, Reliefweb.int, UNDP, UNEP) and NGO's ICRC, Save the Children were searched for relevant publications (table 11, annex 2). Government websites of Malawi were searched for relevant publications (table 12, annex 2).

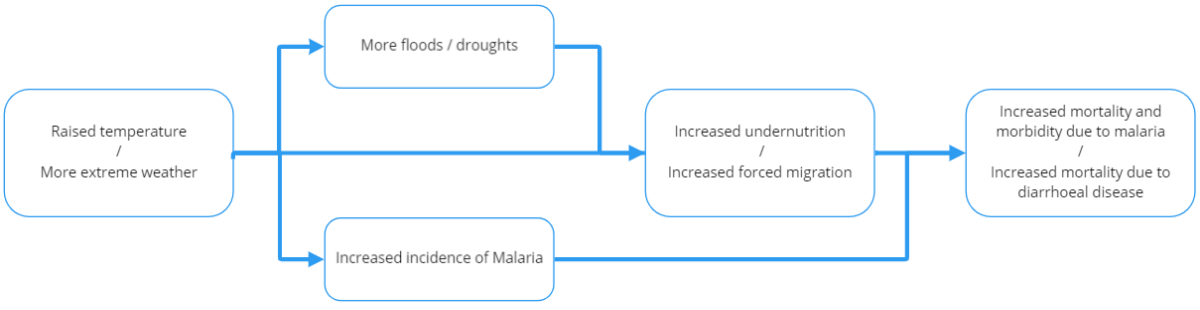
Selection strategy

If a search query resulted in more than 100 results, the search results were narrowed down by first removing the "OR" from the search query and secondly by restricting the publications to the last 25 years or if needed the last 10 years. Search results were screened initiatially by title for relevance to the search query. If the title seemed relevant for the search query the abstract was sceened. Artricles were included if the subject was relevant for the search query or the objectives, and full texts were available and written in English. Articles were excluded if they were not addressing the (sub-) objectives of this thesis. Because of the large scope of this topic, it was not feasible to perform quality assessment in a systematic way. To achieve saturation on a subject snowballing (going throught the references of the included articles) was used to screen for articles that could be relevant for the search query or objectives.

Data analysis

The results of the literature search were organised corresponding to the analytical framework with the first chapter on "Climate change and Malawi", followed by the chapters on "Direct and indirect effects", "Increased risk of disease" and lastly "Child health effects". An example is shown in figure 15. Results that were found using the framework and the included articles, that did not address the main or sub-objectives are added in the supplementary materials in annex 5. For map making QGIS 3.16, Hannover was used. For statistical analysis Microsoft Excel 2021 MSO was used.

Figure 15: Climate change effects as distal (left) and proximal (right) determinants



Since the analytical framework is following a cause - effect approach the output is not guided towards policy in a certain way other then mitigation and adaptation. It does not include all aspects mentioned in frameworks describing the Social Determentints of Health (SDH) like the ones of Mackenback et al (111), Dahlgren and Whitehead (112) and the framework of the Commission on SDH by WHO (113), see figures 16-18. Therefore the overall policy framework of the SDG's was used to guide the discussion section and to make suggestions and recommendations based on the results of the literature review. There is expected to be an overal good overlap between the areas covered in the SDG's and the expected results.

The results of this thesis will be shared with the Ministry of Health (MoH), in charge of health system related affairs and the Ministry of Forestry and Natural Resources, in charge of the climate change related affairs. For advocacy purposes this thesis shall be shared with UNICEF, the Dutch Society for Tropical Medicine & International Health and the Dutch Pediatric Society.

Results

Chapter 1 Climate change and Malawi

This chapter contains the most distal determinants of climate change on child health. The results will therefore mostly contain information that affect more proximal determinants and not child health directly.

Climate change

- Extreme weather (rapid and delayed)
- Altered rainfall
- Raised temperature (maximum and average)
- Sea level rise
- Acidification of oceans

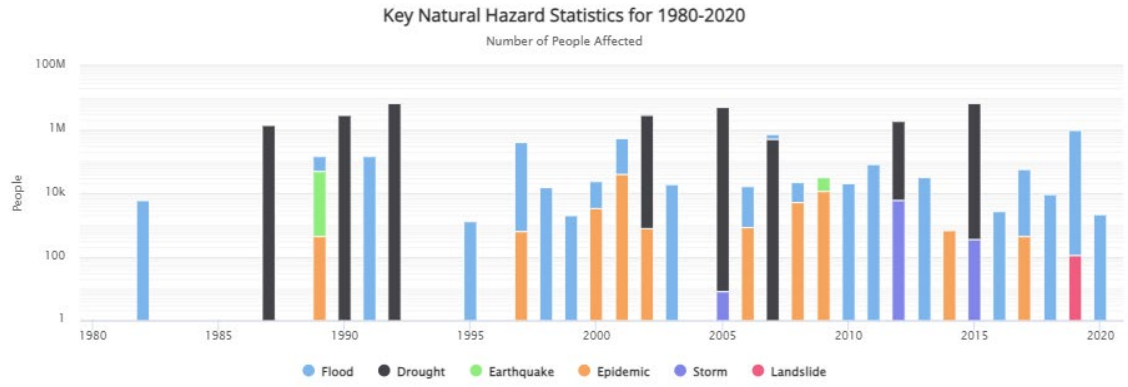
Extreme weather

Malawi is particularly prone to dry spells, seasonal droughts, intense rainfall, riverine floods, and flash floods but also earthquakes, landslides, heat waves, cold snaps, strong winds, tropical cyclones, tornadoes, hailstorms and thunderstorms have occurred in the past 50 years (68,69,80,114–117). Reports of extreme weather in Malawi (cyclones, droughts, floods, hailstorms, landslides and strongwinds) increased from just 6 in the 1970's to 69 between 2000 and 2008 (117). Natural hazards that happened between 1980 and 2020 and the amount of people they affected, are shown in figure 18 below.

Climate models indicate frequency, intensity and duration of extreme weather events (EWE), such as floods, droughts, cyclones and extreme temperature events are projected to increase due to climate change in Malawi, which will increase its vulnerability (48,55,115,118–121). For an explanation see box 1 on the next page. Due to climate change the frequency of extreme El Niño events is projected to double, increasing the likelyhood of heat, droughts, floods and strong winds in Malawi (68,117,122).

Frequent and widespread occurrence of shocks have caused many people to move in and out of poverty resulting in "virtually no progress in reducing poverty and inequality over the past decade in Malawi" as reported by the World Bank in 2007 (123). The most common shocks are weather-related leading to 1) drops in crop yield, 2) loss of livestock 3) increased food prices threatening local and national food security 4) internal displacements 5) damaged infrastructure 6) health impacts and 7) direct casualties (55,123,124). In the NDC plans are communicated to form community-based early warning systems for multiple hazards (68).

Figure 19: natural hazards in Malawi (World Bank)



Source: World Bank, climate change knowledge portal (114)

Box 1: How does climate change cause increases in extreme weather?

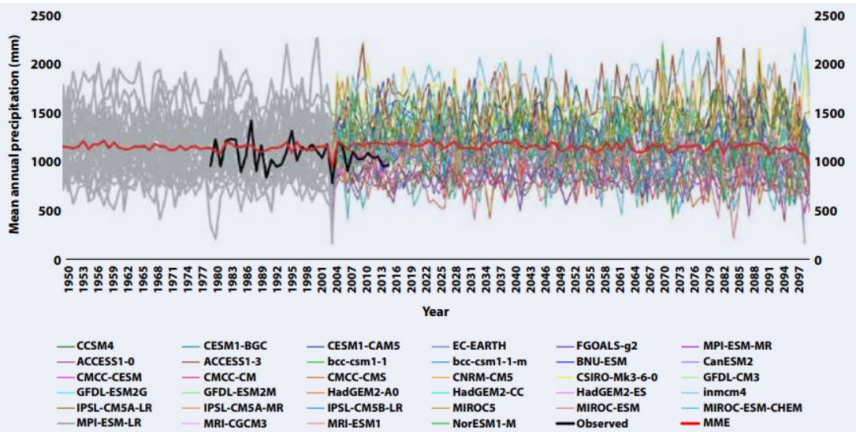
It starts with the understanding that CO2 and water vapor absorb infrared radiation in the earths atmosphere, emitted by the sun and reflected by the earth's surface (99). This "greenhouse" effect combined with the earths position in the "Goldilocks zone" makes earth habitable to humans (99). The accumulation of CO2 in the atmosphere, mostly due to the burning of fossil fuels, has already warmed the earth with around 1.09 degrees Celsius (6). Due to this global warming the air can hold more water, this results in higher evapotranspiration (evaporation from water surface areas and soil, including transpiration from plants) and thus increased humidity (214). By increasing the amount of water vapor in the air / atmosphere a positive feedback loop forms since water vapor itself is a greenhouse gas, it is estimated this effect doubles the warming due to CO2 alone (214).

The additional effect of this additional water vapor in the atmosphere is the increased latent heat/energy, it takes around 2265 kJ/kg water to change phase from liquid to gas, that same amount of energy is released when it condenses back into liquid water, which leads to more extreme weather (214,215).

Altered rainfall

Rainfall projections are subject to greater uncertainties than temperatures projections and models show disagreement on future patterns in Malawi (125,126). For southern Africa later onset of rainy season and general decline in precipitation / rainfall has been projected (115,127). In the past century rainfall has been gradually decreasing in Karonga (North of Malawi) (17). At community level, smallholder farmers in the southern region of Malawi have noticed a shift in the onset of first rains, in the past decades onset of first rains was around October/November, now it tends to lean towards November/December (17). Mean annual rainfall projections in Malawi did not reveal a strong increasing or decreasing trend (126), see figure 20.

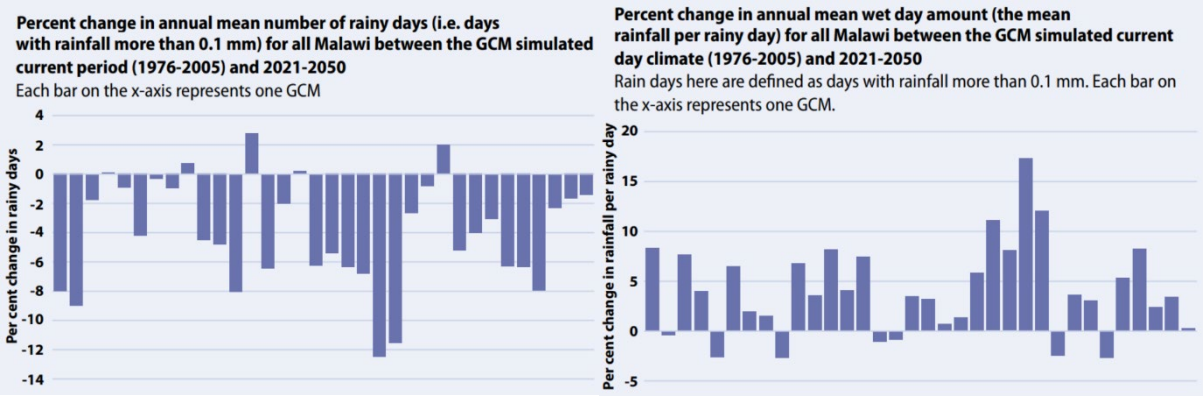
Figure 20: Annual rainfall for Malawi in 34 CMIP5-models, ensemble mean in bold red



Source: Future Climate For Africa (FCFA) (126)

Projections do show a decrease in annual number of rainy days and an increase in the mean amount of rainfall per rainy day as shown in figure 21, next page (126). So it means rainfall variability will increase with a higher likelyhood of dry spells and intense rainfall events associated with floods (48,126). The effects of increased rainfall variability will be discussed in the subheadings "Precipitation and floods", "Droughts and wildfires" and "Food insecurity".

Figure 21: Percentage change in mean days with rainfall and rainfall per rainy day, Global Climate Models on the x-axis

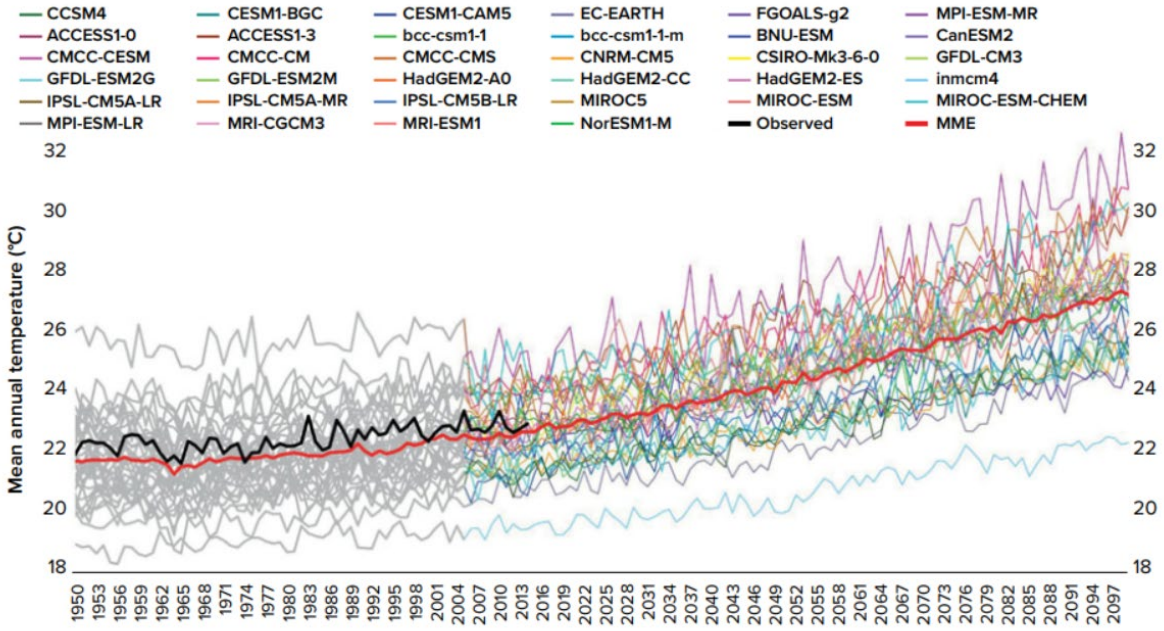


Source: Future Climate For Africa (FCFA) (126)

Raised temperature

Mean temperature in Malawi already increased by 0.9°C between 1960 and 2006 (125). Compared to baseline the mean annual temperature is projected to increase by 1.6-2.0°C in 2050 (ibid) and could increase with 2.3-6.3°C in 2090 compared to baseline, see figure 22. This will cause higher evapotranspiration and consequent water stress (12,48,128)

Figure 22: Time series of mean annual temperature (C°) for 34 CMIP5 models



Source: UMFULA. 2017. *Malawi Country Climate Brief: Future Climate Change Projections for Malawi.*

Note: CMIP = Climate Model Intercomparison Project.

Source: Future Climate For Africa (FCFA) (129)

Sea level rise

No literature was found of the projected sea level rise impacting child health in Malawi. It does affect the coastal areas of Mozambique (130). Supplementary information in annex 5.

Acidification of oceans

No literature was found on the projected acidification of oceans impacting child health in Malawi. Accumulation of pollutants and toxic metals due to acidification are outside the scope of this thesis. Supplementary information in annex 5.

Chapter 2 Direct and indirect effects

This chapter builds on the results of chapter 1 and contains more proximal determinants of child health. First the direct effects will be discussed and hereafter the indirect effects.

Direct effects

- Temperature changes
- Precipitation and floods
- Droughts and wildfires

Direct effects

Temperature change

Direct effects of heat waves / hot days on child health are outside the focus of thesis. Supplementary information is provided in annex 5. Effects of temperature change on the focus topics are discussed in the corresponding headings.

In 2005 a study was published in which mortality amoungst children under 15 increased with 3.2 to 4.2% for each degree above 20°C in Delhi, a city with high air pollution, compared to 0.6 to 1.1% and -2.2 to -3.0 in Sao Paulo and Londen respectively, obviously many confounders could influence this effect but nevertheless the found results are significant for low-income countries.

A study on lake Tanganyika in Tanzania has shown declines in commercially important fishes (55,131). In Malawi no such analysis has been done but Lake Chilwa in Malawi has been reported to have risen by approximately 1°C and precipitation has slightly decreased (132). This could have potentional consequences for food security and infectious diseases.

Precipitation and floods

Climate change has contributed to the heavy precipitation during the tropical storm Ana in 2022, a once in 50 year event, which caused widespread flooding (17,133). The timing of these events have consequences for food security: excess rainfall during the first two months of the growing season had an adverse effect on consumption per capita in Malawi, reducing consumpsion by 1-2% for each day of excess rainfall, excess rainfall in the following months of the growing season increased consumption by 1% (116).

The devestating consequences of EWE in Malawi are shown in figure 23, next page and described in annex 6. Malawi has experienced 33 floods from 1980 until 2017 according to numbers of the World Bank and 144 floods from 1980 until 2008 according to the Third National Communication to the COP (55,117). Floods have lead to loss of crops, decreased yields, reduced access to safe drinking water, spread of waterborne diarrheal diseases and vector-borne diseases such as malaria, damage to key (health) infrastructure, pushing households into poverty due to loss of assets and livelihoods, internal displacement and reduced economic activity and output (55,69,81,121,124). All of these effects cause changes in more proximal determinants of child health which will be discussed in the following chapters and subheadings.

New technologies have been helpful in the aftermath of floods, drones were succesfully used in 2019 for flood mapping, cholera risk assessment, identifying flood-prone areas for mosquito breeding sites, pick-up of medical samples and delivery of medical commodities (134). Early warning systems are being developed and already were successful during the flood preparation during the El Niño of 2015-2016, the forecasts helped decide to focus preparations in the north of the country instead of countrywide which saved resources and at the end no lives were lost due to flooding in the north of the country (70).

Based on a broad analysis using median climate scenario directly related to temperature and precipitation changes through to 2050 it is estimated that Malawi is facing potential annual average costs of 165 milion USD until 2050 without adaptation measures applied to planning, construction and maintenance road infrastructue (48).

Figure 23: Flooded village in Lower Shire in 2015 after the highest rainfall on record

Source: Malawi 2015 Floods Post Disaster Needs Assessment Report (124)

Droughts and wildfires

Most severe drought episodes that Malawi experiences are caused by the El Niño / Southern Oscillation (68), see box 2 next page. Malawi has experienced 8 major droughts from 1980 until 2017 (55). Increased dry spells and droughts can have nationwide repercussions by 1) threatening food security through reduced crop yields and livestock production which can lead to famine and starvation, 2) changes in access to natural resources (e.g. clean drinking water), 3) increased risk of infectious diseases and 4) reduced economic activity and output 5) increasing the risk of wild- and forestfires (55,68,121).

The prolonged drought in 2016-2017, which was cause by the strongest El Niño event in 35 years, together with the floods in 2015, resulted in 6.7 million people being food insecure in 2016-2017 (135). This drought was estimated to have caused a reduction in GDP growth of around 2.2 percentage points making Malawi one of the worst impacted amoung affected countries in the SADC (48).

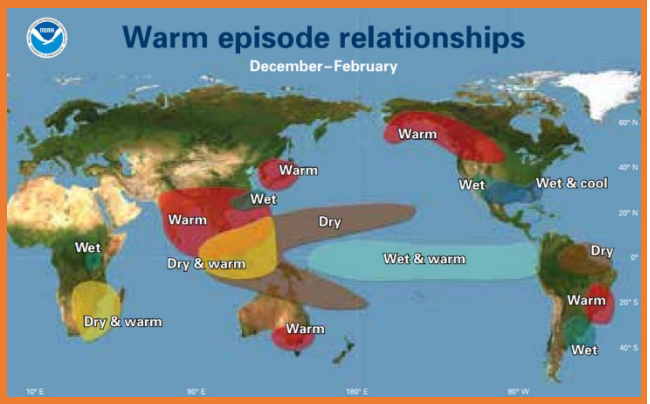
Like with excessive rainfall the timing of the droughts is also important. Malawi has experienced more droughts (in this study defined as a 30 day long dry spell) during growing seasons in the past decade (54%) compared to the decade before (39%) (136). This means that in the past 20 years almost every other year a drought occurred during the growing season (ibid). Droughts during crop growing season decreases consumption per capita without food aid by significant margins of 5-12% (116).

Women with no other subsistence options may resort to selling sex for money and it is not uncommon in southern Africa for girls to be married off early in times of drought (115). In 1995 a period of extended drought was responsible for the complete drying out of lake Chilwa which resulted in total loss of fish stocks (17). The drying of Lake Chilwa was associated with an increased number of early marriages in daugthers (72). Children born from adolescent mothers have an increased risk of mortality, severe stunting and onset of illness (137). In 2017 the constitution of Malawi was changed raising the age of legal marriage from 15 to 18 years (138).

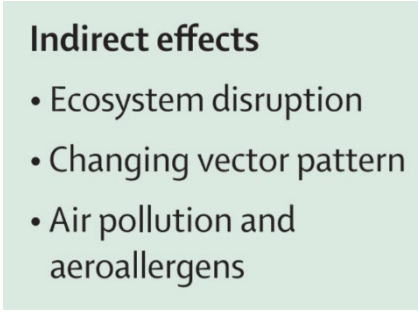
Forestfires and wildfires causing large amouts of smoke impacting air quality are more seen during and after droughts, this smoke is harmfull even over long distances, children under 12, who breathe twice as frequently as adults, could be particularly impacted (139).

Box 2: El Niño / La Niña (216)

The El Niño / Southern Oscillition (ENSO) comprises three phases: El Niño, La Niña and neutral. El Niño and La Niña are the oceanic components while the Southern Oscillation is the atmospheric component. El Niño events begin with large-scale warming of surface water in the central and eastern Pacific heating the overlying atmosphere, causing the air in the east to rise after which it cools and produces rain. In the western side of the Pacific the ocean surface tends to be cool causing less rising air. This is combined with higher air pressures in the west and lower air pressure in the east. During La Niña events the opposite happens as during El Niño events. El Niño usually peaks during November – January and then decays over the following 6 months. So far it occurs approximately every 2-7 years and can last up to 18 months.



Indirect effects



Ecosystem disruption

Due to the rising temperatures and EWE ecosystems will be disrupted, even a relatively small change in average temperature can have a major impact on biodiversity and the ecosystems we depend on (139). If one species is unable to survive, then all of the species that depend on it are threatened (ibid). One study found that 20-30% of plant and animal species are at high risk of extinction as a result of 2-3°C increase in global mean temperatures (ibid). This could have severe consequences for the agricultural sector and food security. Loss of Oreochromis Shiranus (fish species) was so severe that Lake Chilwa had to be restocked from Lake Malawi (17).

Human activitity is also a cause of ecosystem disruption, the conversion of natural ecosystems and habitats is mainly the result of deforestation from agricultural expansion and increasing demand and use of biomass energy which continues to be the main source of energy for most Malawians (17), see box 3.

Majority of women in Malawi are informally employed in the natural resource sector and their livelihood and food security are more likely to be adversely affected by deforestation, land degradation and resource depletion, 90% of women over 15 state that they are reliant on natural resources for domestic activities (like fetching water, collecting wild fruits, collecting firewood) in comparison to 24% of men (55). No relevant studies were found on ecosystem change impacting child health through climate change in Malawi.

Box 3: A double edged sword: environmental degradation

Majority of rural families depend directly and heaviliy on natural resources for their livelihoods, wood fuel supplies consists of nearly 90% of national domestic energy need (55). Woodland degradation and soil erosion increase the vulnerability to extreme weather events like floods and droughts (48). Land clearance for agriculture and wood fuel harvesting are the leading causes of woodland degradation (48). The use of biomass / wood fuel / charcoal is a source of GHG-emissions.

Non-climate related drivers of environmental degradation in Malawi are deforestation and land degradation, reducing agricultural yields (48,217). It is estimated that wood fuel harvest exceed sustainable yield from forests by 71% (55). Forest cover decreased from 57% to 23% from 1975 until 2019 (68). The loss of forest cover has continued between 1993 and 2018 resulting in the lowest hectarage of forest cover per capita amoung neighboring countries (48). In 2010 land used for agriculture was 48.277 km2 and forests made up 31.635 km2 (55). Groundwater levels have dropped significantly and soil erosion presents a growing challenge affecting 61% of the entire land area in the country (48). The woodland degradation will cause a reduced watershed protection, which in turn will have health effects by increasing the risk of diarrhea in rural households (48,218)

Changing vector pattern

Dengue fever, chikungunya, malaria and yellow fever cause significant health impacts and are highly sensitive to changing climatic conditions by exerting influence on the life cycle of the vectors (72). While an increase in mean temperature may allow the diseases to expand to higher altitudes and lengthen the transmission season, drier conditions may depress the spread of malaria (121). Droughts, temperature rise and other climate extremes can also influence food supply indirectly by altering the ecology of plant pathogens and pests (140).

Due to climate change Malawi will be increasingly suitable for ticks who can cause “East Coast Fever”, one of the most important cattle diseases in Africa, caused by the parasite Theileria parva (72,141).

Transmission of malaria typically peaks at 25°C and 28°C, in highland areas above 2000 meters, temperatures are currently to low for transmission but these areas are expected to experience malaria epidemics as temperatures rise, in the Bolivian Andes malaria transmission has reached 2300 meters (139). Studies of malaria have revealed the health impacts of interannual climate variability associated with El Niño (140,142,143).

In Malawi longer warm conditions increase the incidence of malaria across 7-9 months rather than the historical 3-4 months (January-April) and expands the range towards the highlands (72). An increase in mosquito populations in locations such as Mzuzu and the Viphya Plateau at 1200m elevation is already being felt with current temperatures more frequently being above 15°C and “Malaria is now even more common in highland places like Kasungu, Ntchisi and Rumphi”(ibid).

Air pollution and aeroallergens

Air pollution is increasing the vulnerability to communicable and non-communicable respiratory diseases (127,144), box 4. Climate change affects air pollution through several pathways: raised temperature increases evapotranspiration and drought which is associated with 1) an increase in wildfires and 2) an increase of Particulate Matter of 2.5 micrometer (PM2.5) due to decreased precipitation and due to windblown dust and 3) the raised temperature increases the amount of harmfull groundlevel ozone and pollen which are known triggers of childhood asthma (127,139,145). Higher atmospheric CO2 concentrations and warmer temperatures are likely to increase ambient pollen levels (30). Increases in ambient temperature and ozone levels directly correlate with pediatric emergency department visits for asthma exacerbation in other settings (146).

Children are more vulnerable to air pollution because of their faster respiratory rate, their exposure (more outdoors playing, more indoors near fire) and their ongoing development which can cause harmful and irreversible effects on the development of the lungs due to expore to air pollutants (62,139,144,147). Higher ambient temperatures are linked to greater respiratory uptake and toxicity of pollutants such as ozone which could increase vulnerability to heat (147). Maternal exposure to PM air pollution and ozone was associated with adverse birth outcomes like Low Birth Weight (LBW), Small for Gestational Age (SGA) and Preterm Birth (PTB) (144). Postnatal exposures to air pollutants (including PM, ozone and nitrogen dioxide) have been associated with increased infant mortality (ibid). Prolonged pollen seasons, associated with increases in asthma and allergic reactions, are depend on the combination of increased temperature and greater precipitation (12), it is to be determined whether this is applicable to Malawi and therefore needs special consideration. Although there are some studies done in Malawi on the effects of ambient air pollution, none were targetted at children.

Box 4: Climate adaptation & health co-benifits

Indoor (household) air pollution causes 534,000 under 5 deaths every year globally and outdoor (ambient) causes 127,000 under 5 deaths annually (139). The burning of bio- and fossil fuels causes CO2 emissions and a.o. harmfull PM emissions which cause air pollution (139,144). In Malawi 95% of people cook using biomass fuels and many depend on open fire cooking or inefficient cookstoves, access to electricity continues to be limited (219). This results in extremely high levels of household air pollution which is know to have a strong correlation with the occurrence of pneumonia among children (55,220). With increasing mean temperatures and constant emissions of precursor chemicals, such as nitrogen dioxide from fossil fuel combustion and biological processes, ozone concentrations are projected to increase (12). With reductions in wood fuel and fossil fuel combustion effects on respiratory health could be reduced. Unfortunately it is not as easy as providing cleaner cooking stoves (220).

Chapter 3 Increased risk of disease

Increased risk of disease

- Food insecurity and malnutrition
- Educational attainment
- Forced migration
- Toxicant exposure
- In-utero exposure

Food insecurity and malnutrition

In the Burden of Disease study from 2004, climate related food insecurity and undernutrition constituted the largest contributor to climate change mortality (33,121). First the impact on national food security will be discussed followed by the impact on household food security and closed by the impact on undernutrition. The impact of climate change is expected to be aggravated by population growth, unsustainbable agriculture and increased deforestation leading to reduced watershed protection (55), as touched upon in box 3. This puts Malawi's socioeconomic position at risk which could lead to increases in poverty and food insecurity (ibid).

National food security: Frequent floods and droughts, which particularly affect the southern regions, are the leading cause of chronic food insecurity nationally (72). In 2005, responding to the worst maize season in a decade (40% below the long term average), the Government of Malawi (GoM) implemented a Farm Input Subsidy Program (FISP), subsidizing maize seeds and fertilizer which resulted in the 43% national food deficit to become a 53% national food surplus (148). The maize season (October 2004 – June 2005) was impacted by drought in the important months of January and February (ibid). The FISP is still used in the agricultural sector (149). But in the past years Malawi has been reliant on international assistance to achieve national food balance (60). In 2015 undernutrition was associated with 23% of child mortality cases in Malawi (72). Social protection programs generally target the poor, these programs could be horizontally expanded to the households who are vulnerable to poverty in the aftermath of disasters which would require an ex ante identification of these households (116).

Increased temperatures affecting yields: National food security is closely linked to maize harvest and access to maize (128). Maize crops account for 80% of cultivated land and 60% of caloric intake in Malawi (72). Increased temperature will cause 25% average yield losses for maize (scenario of 4°C rise by 2100) in low-latitude regions (latitudes between 30N – 30S DD, Malawi is within this region with 13S DD latitude) vb , based on crop growth models that incorporate the effects of CO2, temperature, water availability and nitrogen limitation (150). On the short term maize yield might benefit from climate change (negatively impacting soil fertility) but on the medium and long-term lower maize yields are expected to exacerbate vulnerability to food insecurity due to the projected population growth (128). African inland lakes contribute significantly to food security, livelihoods of rural communities and to national economies (151). Due to increasing temperatures fishery production could possibly decrease based on a study from Tanzania (131).

Extreme weather affecting yields: Decreased crop yield caused by extremes in rainfall (both too much and too little and at the wrong time) leads to increases in the market price of food which impacts poorer people's access to sufficient food (72). The consequences of several EWE are more in detail described in annex 6. Summarizing: huge loss of crops (figure 24, next page), increased food prices, lower yields and production, increases in admissions to malnutrition programmes and decreased consumption of food.

Food insecurity is quite spread through the country when looking at figure 4, annex 1. With the most EWE occuring in the south of the country as stated in chapter 1 and shown in figure 5, annex 1, it could be an explaination why the southern region is at increased risk of stunting, wasting and underweight compared to the central and northern region, by exacerbating the already existing food insecurity (152). Floods and droughts frequently reduce the size of harvests which can have significant negative implications for nutrition and

stunting (48,153). The vulnerability of smallholder farmers has increased with average declines of value per hectare of 42-44% (154). Besides these effects they can also cause micronutrient deficienties despite adequate caloric intake (ibid). Sustainable land management techniques improve resilience to floods and droughts with proven effective examples like legume intercropping and using green belts, but use remains limited to farmers with greater wealth levels (154).

The fisheries sector is affected by both droughts and floods, during droughts water bodies declined or even dried up and during floods fish ponds were destroyed (17).

The effects of climate change on plant- and livestock pests in Malawi are outside the focus of this thesis.

Figure 24: Destroyed crops during the floods in 2015

Source: Malawi 2015 Floods Post Disaster Needs Assessment (124)

Household food security: Maize is the primary source of calories with a high consumption of 382 gr/capita/day (128). Fish account for 60% of all animal protein at the household level (17). Micronutrient deficienties are common, with anemia affecting 60% of all children under five (69). When maize is the main source of food for example in times of poverty, children will have a high risks of micronutrient deficiencies, see annex 8. After the drought of 2016 price of maize increased which affected not only the rural poor but also the urban poor, decreasing per capita food consumption by 6% (48,116). Availability of food when displaced also compromises food security (72). The post-disaster needs assessment after the tropical cyclone “Idai” indicated that the income was affected of 500,000 farmers and small businesses, increasing poverty (69,116). Greater variability in agricultural incomes in the face of climate shocks and displacement will present even greater challenges for rural households, due to limited assets and a lack of access to finance, many rural households already lack the ability to smooth consumption across harvest and lean seasons (48,72). Households may be forced to sell productive assets in times of food insecurity (60). Vulnerability to poverty is generally higher than static poverty in Malawi and the past weather shocks have pushed these non-poor vulnerable households into poverty (116).

Malnutrition: In the CCRA from 2014 an additional 500,000 children are projected to have moderate stunting and 1.8 million children severe stunting in 2030 in Eastern Sub-Saharan Africa (which included Malawi), the additional deaths due to undernutrition are estimated to be 27.999 (table 10, annex 2) (34). Climate change is likely to increase exposure to undernutrition in Malawi and subsequently the chance of mortality (48,66). It exacerbates existing rates of undernutrition through impacting sufficient, safe and adequate food, impacting care and feeding practices and impacting environmental health and access to health services (48). Women play a key role in ensuring food is available to the family especially their children (17). This is impaired by poverty: the prevalence of stunting was 46% in the lowest wealth quintile, compared to 24% in the highest wealth quintile in recent data from 2019 (60). Nutritional status of (pregnant) women is also negatively influenced by all that was mentioned above. Children born from mothers who are thin (BMI<18.5) are more likely to be stunted, wasted or underweight (60), so the nutritional status of (pregnant) women has a strong link with the childs nutritional status. Droughts are causally related to stunting and other child malnourishment outcomes (136). In 2010 it was stated that the health sector in Malawi is expected to see an increase of malnutrition due to climate change (17). During the drought period in 2016 Malawi saw a significant increase in new admissions of SAM and MAM (81). The national health policy promotes several nutrition specific interventions like de-worming, provision of insecticide treated bed nets, treatment of malnutrition and micronutrient supplementation and the National Resilience Strategy supports scaling up the School Meals Programme (60).

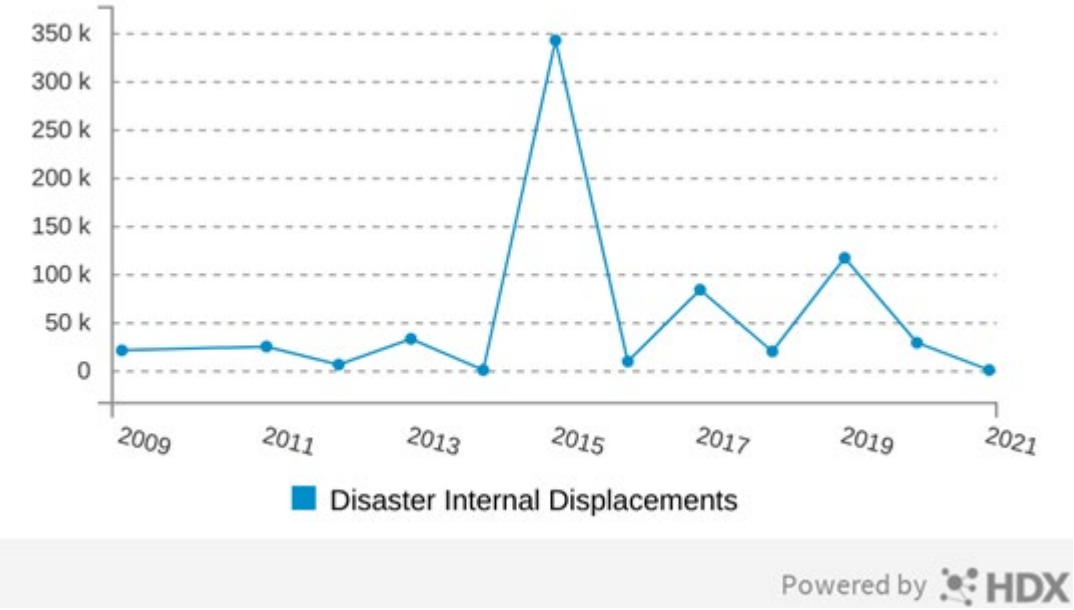
Educational attainment

The cycle of educational attainment as a determinants of nutritional status (UNICEF framework) and nutritional status as a determinant of educational attainment (early childhood development) are well understood and will not be described here (123,153,155). The effects of the focus topics on educational attainment are described in their corresponding headings. It is deemed beyond the focus of this thesis to expand on how climate change affects educational attainment in other ways. Supplementary information in annex 5.

Forced migration

The major reason for forced migration in Malawi has been EWE leading to Internally Displaced People (IDP), see figure 25 next page. In general, displaced people, women, children and the elderly are disproportionately at risk due to their limited access to infromation, technology and financial resources (72). The effects of these EWE are described in more detail in annex 6. Internal displacements leads to an increased vulnerability to infectious diseases in various ways: firstly through disruption of routine vaccination services which can cause outbreaks of vaccin preventable diseases (72), secondly they may inadvertantly introduce diseases into new areas as a result of moving (ibid), thirdly by loss of shelter people have insufficienct access to mosquito nets, having lost the one they owned (69,124). Fourthly they are more at risk of diarrhoeal because of insufficient water, sanitation and hygeine (WASH) facilities at the IDP camps and loss of water supply equimpent (69,72). Fiflty people are more exposed to sexual and gender based violence (SGBV) leading to sexually transmitted infections (STI) (ibid). Sixtly due to decreased access to (primary) care because of infrastructure damage but also due to unavailability in IDP camps treatment options for infectious diseases might not be available (124). The effects of forced migration on food security have already been discussed. The loss of physical assets due to extreme weather increases poverty (72).

Figure 25: Internal displacements after disasters in Malawi



Source: Humanitarian Data Exchange (156)

In- and ex-utero (toxicant) exposures

The effects of in- and ex-utero exposure of children to pollutants and toxic metals are outside the focus of this thesis. The effects of in- and ex-utero exposure to air pollution, undernutrition and infectious diseases are discussed in the corresponding sub-headings. Supplementary information in annex 5.

Chapter 4 Child health effects

Direct mortality and morbidity from extreme weather events (EWE)

The direct effects on mortality and morbidity from EWE are outside the focus of this thesis. Supplementary information in annex 5.

Infectious diseases

Climate change impacts the effect of infectious diseases in various ways: by changing the burden of disease, through increased exposures, through decreased access to WASH facilities and healthcare and by increasing the vulnerability of children. Specific focus on infectious diseases who are closely linked to the functioning of the health system are discussed seperately: vaccin preventable diseases, vector borne diseases and waterborne diseases. How health facilities were damaged during the EWE is described in annex 6.

Health effects

- Direct mortality and morbidity from extreme weather events
- Infectious diseases:
  - Vector borne
  - Water and food borne
  - Respiratory pathogens
  - HFMD
  - Other*
- Respiratory diseases
- Mental health
- Other health effects concerning: skin, immune, endocrinological, metabolic, and neurological systems

Changed disease burden: In Malawi increased incidence of malaria, cholera and dysentery is expected due to climate change (17). Increased temperatures are associated with an increased incidence of bacterial causes of diarrhea (146). Droughts have increased the prevalence of scabies and dysentry in Malawi and floods have increased the prevalence of malaria, cholera and schistosomiasis (81). The risk of new emerging infectious viral diseases might be past the mitigation phase. The ecological transition may already be underway and holding warming under 2°C within the twenty-first century will not reduce future viral sharing, urging the need for adaptation measures like improved viral surveillance and discovery efforts (29). Higher temperatures will cause an increase in food-borne (diarrhoeal) diseases for example due to salmonellosis (48,140).

Increased exposures/vulnerability: EWE contribute indirectly to mortality through spread of diseases for example through contact with contaminated water after a flood or increased food insecurity and undernutrition (72,121). After floods girls were often required to travel long distances to collect water and firewood exposing them to sexual abuse and other forms of violence (69). Food insecurtity and displacement due to extreme weather and unfavorable rainfall conditions may lead to an increasing trend in women engaging in transactional sex e.g. fish for sex which increase the risk of HIV (72), also the marriage of children / adolescents, in response to droughs, to older men who have had numerous sexual partners, could increase this risk of contracting HIV (115). The risk factors for inpatient child deaths in a large cohort study were: being under 2 months, poor nutritional status and exposure to HIV (66). Exposure to disease in-utero and during early life (like malaria or cholera) have been found to negatively impact cognitive development and educational outcomes (155).

Reduced access: as mentioned above access to care was compromised by the EWE. In a large cohort study over two-thirds of malaria cases died within 24h after admission which might suggest that late presentation to the hospital was a significant contributory factor (66). After the floods of 2019 an estimated 460,000 children lacked basic supplies like food, water and access to toilets (134).

Vaccine preventable diseases

The health gains of vaccinations should not be taken for granted. Communicable disease outbreaks are primarily caused by displacement or a disruption to routine immunization services (72). The EWE have the power to disrupt this otherwise successful strategy: the shutdown of the power plants for more than 48 hours in 2019 during the tropical cyclone “Idai” and the damage to the important hydropower plant Kapichira due to the tropical storm “Ana” in January 2022 are examples were the cold chain for vaccines can be broken (158). Apart from the direct effects of these events “immunizations were seriously disrupted in six health facilities of Makhanga, Mbenje, Bereu, Ndamela, Gaga and Chithumba for 19 days” (ibid). Heat stress can also be challenging in cold chain management, as certain microbes multiply faster and more efficiently under higher temperatures (139). Droughts have been associated with decreased BCG and measles vaccination and positively associated with polio vaccination in Malawi (159). In February 2022 Malawi declared an outbreak of wild poliovirus type 1, which was the first outbreak in Africa in more than 5 years (160).

Although the incidence of Acute bacterial meningitis (ABM) dropped from 2002 until 2012 after introduction of Haemophilus influenzae type b (Hib) vaccination in 2002, rainfall was associated with 28% fewer cases of ABM due to pneumococcal meningitis, hot weather was associated with 42.8% more cases (72,157).

Vector borne disease

Malaria

The whole population of Malawi is considered to be exposed to high transmission of Plasmodium Falciparum malaria which is the leading cause of mortality and morbitidy in children and pregnant women (72,161). As seen in table 3, annex 2, malaria has remained in the top 5 causes of child mortality from 1990 to 2019. It remains a major public health problem in Malawi with an estimated 6 million cases and it accounts for over 30% of Out Patient Department (OPD) visits and 18% of all hospital deaths (161,162). Case fatality rate has decreased from 46% in 2011 to 24% in 2014 (161). Important for the aftermath of disasters: Teenage mothers were less likely to take preventive measures for ensuring better health for their children, they had 20% lower odds of sleeping under a bed net compared to children from older mothers (137).

Under all emission scenarios the range and incidence of Malaria is projected to increase, with population growth being a contributing factor to those at-risk in areas where the presence of malaria is a constant in the future (72). Malaria is increasingly being reported in high altitude plateaus and hilly areas that were malaria-free in the last 4-5 decades in Malawi (48). Excluding the considerable increase in population an increase of 16-28% in person-month exposure to malaria risk by 2100 was determined (140). New public health measures like malaria vaccin testing are ongoing with 220,000 children having received at least one dose (163).

Box 5

Plasmodium Falciparum requires temperatures of 18°C for development, at least 20°C is needed to initiate a malaria epidemic (30). At 20°C it takes P. Falciparum 26 days to incubate but only 13 at 25°C (30). Transmission decreases above 28°C

Dengue

Virus infections due to dengue have seen an 8-fold increase in incidence globally in the past two decades, although Aedes Aegypti (the main vector) is present in Malawi no outbreaks have been reported in the last 10 years but there have been outbreaks in the past (164,165). The projected mortality due to Dengue in the CCRA is low in 2030 and 2050 (see table 10 in annex 2). Other infections caused by the the vector A. Aegypti are chikungunya, Zika and yellow fever. There have been no significant outbreaks of chikungunya, Zika or yellow fever since 2000 (165). Chikungunya has been reported in the past, so far there have been no reported cases or serological evidence reported from infections by Zika or yellow fever in Malawi.

Other vector borne disease that pose major health risks for children are Japanese Encephalitis (JE) and schistosomiasis (166). It is not known whether climate change is contributing to the spread of JE spread but the first report on African soil was reported in Angola, Malawi does seem suitable with a growing amount of rice paddies and pig bites which are important for the Culex vector (167). Schistosomiasis is already prevalent around Lake Malawi, reinfection occurs rapidly especially among children aged 6-12 years that live along the lake shore making mass drug administrations alone not effective enough in its control (168). No specific information on changes of incidence or prevalence due to climate change was found, but floods could wash the snails to downstream areas (72).

Water borne diseases

Diarrhoeal diseases were the cause of death for 8.8% amongst children under 20 years old in Malawi in 2019, this has decreased from 17.8% since 1990, see table 3, annex 2 (67). The majority of the population 87.9% (range 84%-97% for wealth quintiles) has access to improved sources of drinking water (169). Contamination of drinking water is common with 60% of households with E. Coli (pathogen and indicator of fecal contamination) in source water and only 5% with an improved drinking water source, free from contamination, availaible when needed (ibid). Households using improved sanitation was 80.1% (range 65-95 for wealth quintiles) and 28.2% (range 13-52% for wealth quintiles) of household members had handwashing facility with water and soap present (ibid).

Lack of access to basic sanitation contributes to the high disease burden in the country, especially with floods and droughts increasing communicable disease like cholera and dysentry as a result of further contamination of surface waters (72). Both rising ambient and water temperature increase the growth of V. Cholerae (ibid). In the case of droughts water becomes more scarce and the poorest people tend to resort to unsafe water sources (139).

Cholera outbreaks have been attributed to the severe drought in 2016 associated with El Niño and to disruptions of Water, Sanitation and Hygeine (WASH) infrastructure in the aftermath of cyclone Idai (72). In March 2022 Malawi again declared a cholera outbreak after the tropical storm Ana and Gombe (80). Effects of these EWE on WASH infrastructure is provided in annex 6. Flooding is associated with child morbidity like diarrhea which in turn is associated with high risk of undernutrition (152). Access to improved sanitation appears to be associated with lower malnutrition (123). Floods not only cause short term WASH-problems, in a study of 279 hand-pumped boreholes in Mulanje District it was found that even after initial treatment (shock chlorination) and safety of these boreholes, after 1 year 40% was reinfected with E. Coli and 20% deemed unsafe (170).

Water borne disease incidence such as childhood diarrhoeal disease, are also influenced by ambient temperature and El Niño, the number of pediatric admissions (due to dehydration by diarrhoea) doubled when temperature was 5 degrees warmer then normal during El Niño in Peru (140,171). WHO is supporting Malawi to implement Early Warning, Alerts and Response Systems (EWARS) to identify potential risks for climate-sensitive water- or vector-borne diseases in 4 selected districts (63).

Respiratory diseases

Aerosol pollutants (Carbon Monoxide, Sulferic Oxide, Ozone, Nitrogen Dioxide, PM) are known to increase the risk of development of non-communicable respiratory diseases (NCRDs) such as asthma, chronic bronchitis, chronic obstructive pulmonary disease and allergic rhinitis (127). And (ambient) air pollution is associated with childhood pneumonia (172,173). No studies were found on how climate change effects these (non)-communicable respiratory diseases for children in the Malawian context.

Mental health

This topic is outside the focus of this thesis. Supplementary information in annex 5.

Other health effects

Global studies have shown climate change could alter the dynamics and risk of negative maternal health outcomes, forced child marriages, human trafficking, sexual exploitation and gender based violence (72).

Discussion

Climate change is the biggest threat to global health and the poor will initially suffer the most of its consequences (23). Malawi is one of the low income countries to which this phrase applies. The objective of this thesis is to discuss the main health effects of climate change on children in Malawi focussing on undernutrition, infectious diseases and air pollution. The literature shows an intricate web of cascading effects. The vulnerabilities already existing in Malawi, widespread poverty and undernutrition, population growth with increasing pressures on the natural systems, high dependency on rainfed subsistence farming, high burdens of disease leading to an overburdened health system, all lead to a balance which can easily tip towards disaster. The implementation of the SDG's focus on 3 dimensions: people, planet and prosperity which should address the above vulnerabilities. Climate change is possibly a game changer which could severly limit progress towards these goals if not addressed adequately and urgently. The effects described in the results jeopardise progress towards these goals of which SDG 1-6 are most relevant for this thesis on child health.

Figure 26: The Sustainable Development Goals

Source: ***https://www.un.org/sustainabledevelopment/news/communications-material/***

In the following section the results of this thesis will be discussed in the context of the corresponding SDG's. To improve readability the targets and indicators are shortened, for a reference to the complete targets and indicators see the referenced document (15).

The frequent and widespread occurrence of mostly weather shocks has led to virtually no progress in poverty reduction between 1998 (52%) and 2020 (50.8%) (116,123,174). Reducing at least half of the proportion of population living in poverty by 2030 (target 1.2) seems very challenging if not impossible, especially with EWE predicted to occur more frequently in the future due to climate change (17). With the widespread (future) infrastructure damages due to heavy rainfall, storms and floods also ensuring basic services to all will be very challenging (target 1.4).

EWE have caused many households to lose income or assets (48,116). For children this leads to reduced educational attainment, reduced consumption through increased food insecurity, increased risk of disease all leading to increased risk of undernutriton. Part of the plans in the Malawi National Social Support Program II (MNSSP II) involve expanding school meal programs during shocks (indicator 1.3.1) (175). Due to its location with its vulnerability through geo-climatic factors (69) reducing the exposure and vulnerability to climate related events will be vital (target 1.5). The IPCC states that eradicating extreme poverty, energy poverty and providing decent living standards to all in these regions in the context of achieving sustainable

development objectives in the near term (2030) can be achieved without significant global emissions growth (176).

Climate change is impacting national and household food security through several pathways leading to an increase of child undernutrition. The increased EWE and high intensity rainfall destroy crops, kill livestock, decrease yields and increase food prices which has caused millions of people to become food insecure in the past 5 years (indicator 2.1.2) with increased numbers of MAM and SAM (indicator 2.2.2.). Raised temperature will impact child health through increased food insecurity due by decreased yields (long term), possible decreasing fish stocks and increased water stress.

Based on the CCRA data (tabel 10 in annex 2) both moderate and severe stunting is expected to increase with 1.4 and 1.8 million in Eastern Sub-Sahara Africa (region of Malawi in this assessment). Based on stunting prevalence data of the past 10 years the average annual rate of reduction (AARR) was calculated to be 1.95% (calculation and reflection on this in annex 7). This would estimate the prevalence in 2025 to be 33.5%. This shows that additional effort will be needed to reach the target of 26.3% (indicator 2.2.1). Loss of crops or decreased yields could potentially have devastating consequences for Malawi through its high depency on maize. Diets which are heavily depending on maize meal / corn meal have very poor micronutrient contents, see annex 8. Prevalence of anemia in children is very high with 60% (69) this make reaching indicator 2.1.1. (prevalence of undernourishment) and 2.2.3 (prevalence of anemia) difficult, although indicator 2.2.3 only counts anemia in women aged 15-49.

The costs of not addressing stunting includes a 10.3% loss in GDP and declines in productivity (60). Multisectoral approaches that address food availability, health and sanitation are associated with reductions in stunting rates (136). Also legume intercropping and green belts have been effective in reducing vulnerability to extreme weather (154), with an additional benefit of the higher nutritious content of legumes. In the National Resilience Strategy the focus pillars include resilient agriculture and nutrition, besides the school meals programs no specific actions are mentioned for children (62).

The top 5 causes of under 5 mortality (U5M) are all expected to be impacted by climate change. The progress that has been made in reducing the U5MR is threatened by climate change. Child health in Malawi will mostly be impacted through increased food insecurity, limited poverty reduction, forced migration, reduced access to WASH and healthcare / quality of healthcare, decreased educational attainment, air pollution, direct morbidity and mortality and increased risk of infectious diseases. Although climate change will increase the frequency of EWE, anthropogenic environmental degradation and loss of watershed protection wil increased the vulnerability to these shocks (48).

Infectious diseases

With almost 5000 (12% of total) child deaths due to malaria in 2019 it is still a major cause of mortality (table 3, annex 2). Although the CCRA predicts an increase of mortality due to malaria in Eastern SSA in 2050 this could possibly be less if ongoing public health interventions like vaccination prove succesfull. Due to increased mean annual temperatures reproduction speed is expected to increase and the geographical distrubution is expected to expand to higher altitude areas which could increase the population at risk and jeopardise progress on target 3.3 (a.o. end malaria epidemics). With a projected expansion of malaria to higher areas, testing and treatment options should be expanded there as well. The effects of other vector borne disease on child health are expected to be limited based on literature found, although schistosomiasis could expand its spread due to floodings.

Climate change might increase the risk of new HIV / sexually transmitted infections in vulnerable populations through various pathways but the consequences for children could possible be limited. The amount of pregnant women requiring PMTCT and also receive it approaches 100%. In case the health system will be successful in addressing this need in displaced / vulnerable pregant women then the health effects on children should be limited (indicator 3.3.1 reducing new HIV infections). Diarrheal disease accounts for 8.4% of U5M. With the increased risk of flooding and high intensity rainfall and subsequent contamination of water sources and increases in cholera and dysentry (72) this could reduce progress on target 3.2 (reducing U5MR).

Progress on indicator 3.b.1 (vaccination coverage) could be limited through disruption of health services due to frequent EWE and their subsequent infrastructure damage also by breaking cold chains. The reduction of BCG vaccination in the aftermath of EWE (given directly after birth) implies decreased access to facility based deliveries (e.g. due to damaged roads / health facilities) which could increase the risk of neonatal mortality (indicator 3.2.2.).

Higher temperature and increased air pollution.

No studie were found on the effects of increasing temperatures on ambient and household air pollution to children in Malawi. Due to the high levels of air pollution in Malawi this could potentially have serious consequences for respiratory health for children. Higher mean temperatures could increase the susceptibility to toxicants and (air) pollutants, the extend of this is yet to be determined since studies in low-income countries have been limited. Droughts can also lead to forestfires and wildfires causing large amouts of smoke impacting air quality, this smoke is harmfull even over long distances, children under 12, who breathe twice as frequently as adults, could be particularly impacted (139). Maternal exposure to air pollutants (PM, ozone, nitrous oxides) is associated with PTB, LBW and SGA (144), all of which influence perinatal mortality (indicator 3.2.2. neonatal mortality rate) and could also increase the risk of undernutrition later in the childs life. Postnatal exposure to air pollutants is associated with infant mortality (indicator 3.2.1 U5MR). Unfortunately no studies on these subjects have been conducted in Malawi so the expected change in burden of disease is unknown but could possibly limit progress on target 3.2.1, 3.2.2 and 3.9.1 (reducing mortality due to household and ambient air pollution).

There are several factors linked with climate change that are challenging progress in goal 4. The impact on educational infrastructures has been significant, this combined with an additional 1.3 million children between 5-15 years needing education in 2030, table 2 annex 2, the strain on learning infrastructure will need to be addressed (target 4.1, 4.2, 4a, ensuring education and schools). Due to poverty school fees may not be affordable and child labour will limit children's school attendance. Looking through a life cycle lense: infections in early life seem to impact educational outcomes and maternal education reduces child malnutrition which influences children reaching their potential.

Target 5.2 (ending all forms of violence against girls/women) and 5.6 (universal access to sexual and reproductive healthcare (SRHR)) are compromised by the EWE due to infrastructure damages (health facilities), the decreased availability of condoms in IDP camps and the increased exposure to Sexual and Gender Based Violence (SGBV) in the IDP camps and the prolonged time needed for collecting water and firewood. The indicators (5.2.1, 5.2.2) only consider SGBV for girls aged > 14 years which would disregard all children under 15 years. Target 5.3 aims to eliminate all harmfull practices such as child early and forced marriage, which was increased in the aftermath of EWE to escape poverty of a household, in 2017 the

constitution was changed making it child marriages under 18 years illegal, although this doesn't rule out this still happening, important steps are being made. Addressing poverty and undernutrition by implementing social protection systems (target 1.3) will help preventing this from occuring. When planning public health campaigns it is relevant to consider that within the poor population only 8% of women and 19% of men owned a mobile phone and only 12% of total population had access to the internet (indicator 5.b.1).

In current models mean annual rainfall is not projected to increase or decrease, rainfall variability is projected to increase. This increases the exposure to dry spells and high intensity rain which in itself could decrease food security, increase air pollution and increase the risk of infectious diseases.

Raised temperature causing increased evaporation will lead to increased water stress. Floods and droughts are major challenges to clean water and sanitation with long lasting vulnerabilities to contamination with E. Coli (target 6.1, 6.2, 6.3, access to WASH and decrease water contamination).

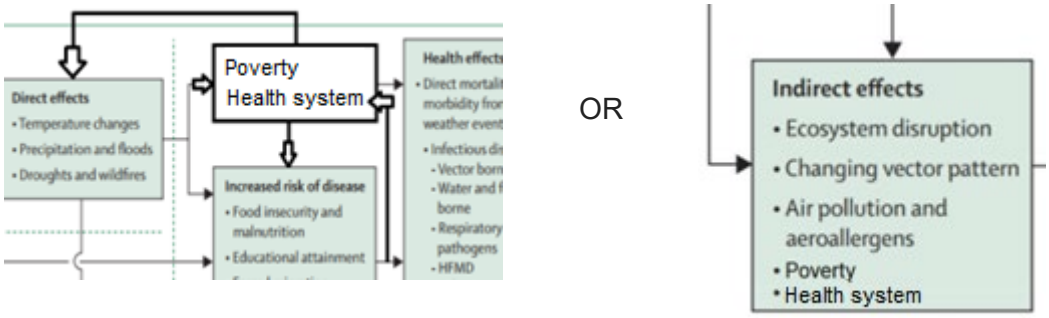
In one study mercury in fish from lake Malawi was not high, but the study is already quite dated (published in 2003), with increasing temperatures and acidification potentially increasing the vulnerability to pollutants, hazardous chemicals and materials (target 6.3), vigilance is important and repeated studies of pollution in relation to climate change would help policy making. It was outside the scope of this study to comprehensively analyse existing literature on pollution of fish in Malawi.

Some reflection on the other SDG's is provided in the supplementary materials, annex 5.

Analytical framework

The strength of the analytical framework comes from the solid base of literature found in the scoping review addressing all available literature on the topic from 2000 to june 2019. By combining different frameworks the final version is very comprehensive. It also explains the links between the distal effects of climate change on more proximal determinants of child health. A limitation of the framework is that its not considering the specific role poverty plays as a determinant of child health. Since poverty is a major determinant of adverse health outcomes in children and also increases the vulnerability to the direct effects of climate change, it would make sense to add a field above “Increased risk of disease” with the field “Increased poverty” with arrows in both directions in the conceptual framework or for example as field in the indirect effects. A suggestion on how poverty could be introduced in the framework is shown in figure 27. The same arguments used for poverty also apply to the health system, by adding it to the framework the role of the health system in the context of climate change can be considered specifically. When developing policies based on the results of the framework, it would be interesting to see what would happen if it were to be combined with the sustainble livelihoods framework, as shown in figure 14, annex 1 (108). This would guide policies for mitigation and adaptation strategies by taking into account the 5 dimension of livilihood assets/capital. On a more theoretical level the framework could benefit from an analysis of the determinants of child health which could additionally be impacted to identify possible knowledge gaps which could provide recommendation for researchs areas.

Figure 27: possibilties for introducing poverty and the health system in the framework



Source: altered expanded framework of Helldén et al (12)

Strengths

The objective of this thesis was to discuss the main effects of climate change on child health in Malawi. By using a comprehensive framework and corresponding search strategy a large amount of literature was reviewed and the main effects on child health identified for the focus topics. By using the clear cascading effects it is explained how climate change is impacting child health in Malawi. When no information was found in the country context, general impacts were described using information from neighbouring countries or comparable settings and the topic was identified as a possible knowledge gap. The identification of vulnerabilities was helped through a comprehensive background description. By identifying the top 5 causes of child mortality helped viewing diseases in the right perspective. By including details on the population growth of children U5 and U15 this century, the continued strain on all facilities and natural resources are clear. By discussing the results in the context of the SDG’s adaptation plans can possibly more easily include the results in following policies.

Weaknessess

Since this literature review was done by one researcher selection bias will play a considerable role. Although a large amount of literature was reviewed it is possible significant papers were overlooked / not found or significant information within papers was missed or misinterpreted. Also no quality assessments of the included studies were made therefore the valitidy of the results might be limited.

When no information was found for the Malawian context and interpolations were made from other countries or global studies these results might be over- or underestimated.

In climate change research it is common to use various emission scenarios combined with scenarios on (global) population growth, economic growth and socio-economic pathways. This thesis did not focus on specific pathways (emissions or socio-economic) the range of the results could therefore also be over- or underestimations. When applying these scenarios to low-income countries this poses also some ethical considerations: when high emission scenarios are used, findings could be overestimated and corresponding adaptation plans underutilized if in the future don't match with real emissions, this could limit the cost-effectiveness of these adaptation plans. In settings were resources are less constrained it is possibly easier to "stay on the safe side". From a global health perspective it makes sense to make comprehensive adaptation plans for the worst case scenarios, then in a not-worst case scenario at least no harm was done. But in a more realistic setting resources will be constrained and difficult choices will have to be made. This is therefor also call for action on the research communities to try and reach concencus on what scenario is most plausible or best defendable, in estimating the future effects of climate change so dicisions can be made based on best available information taking in consideration that low-income countries are even more vulnerable to misinvestments.

Search strategy

The search strategy was not as broad as it could have been, key words were not formulated in the broadest sence of the words represented, this might have impacted the results by not finding relevant papers that did not contain the used key words. However by the rigorous amount of literature reviewed, the many databases searched and the snowballing strategy used in relevant papers this effect was aimed to be limited. In a situation with no time contraints this should be done in a more broad way. Since I was not eligible to use the Research4life databases (HINARI, AGORA, OARE, ARDI) it is possible relevent publications are missed.

Mostly due to time constraints concessions were made on the scope of the thesis and resulted in focussing on undernutrition, infectious diseases and air pollution, this resulted in limited search results in the other chapters and subheadings which are added in the supplementary materials, annex 5.

Ethical considerations:

- Is it justified for low-income / least developed countries to only spend money on adaptation programs instead of mitigation programs, unless they have co-benefits?
- When we apply "primum non nocere" to climate change action / research and its relation to health, what will it imply?
- How can we prepare for the unknown unknowns, the "black swan" effects of climate change?

Conclusion and recommendations

Malawi is currently not on a trajectory to achieve SDG goal 1 (eliminate poverty) and SDG 2 (reduce stunting) in which climate change plays a considerable role. Progress on the targets for U5MR (3.2.1.), ending the malaria epidemic (3.3.3.), mortality due to air pollution and unsafe WASH circumstances (targets 3.9.1 and 3.9.2), educational attainment (target 4.1 and 4.2), eliminate gender based violence and access to sexual and reproductive health services (target 5.2 and 5.6) could be severely compromised by the effects of climate change. There is a considerable knowledge gap on the effects of heatwaves, air pollution, impact on inland lakes and fish stocks/pollution which needs to be addressed.

Extreme weather events are identified as important distal determinants of child health by leading to food insecurity, displacement, undernutrition and increased risk of infecious diseases. Malawi is facing a herculian effort by coping with extreme weather events disrupting its development, population growth, land degradation, food insecurity, double burden of diseases all of which are aggrevated by climate change. It is impacting child health at many levels. The commitment of the world to addressing climate change and the SDG's provides opportunities for financing adaptation strategies and thereby increasing the change of reducing the effects of climate change and the above mentioned factors on child health.

Results of this thesis will be useful for comparable settings but will need contextualization, they could serve as a supplement for policy reviews and as additional justification of climate action by high-income countries.

Recommendations

- For the Ministry of Health address the knowledge gaps mentioned in this thesis would improve decision making for effective adaptation policies
- For the committee updating the NDC, the results of this thesis could be used to increasing the child sensitivity
- For the Ministry of Agriculture it is worth considering the low nutritious content of maize as a staple crop in the face of ongoing and predicted burden of undernutrition
- To the committee updating the National Resilience Strategy, the results of this thesis could lead to better preparedness and limiting the adverse effects on children due to extreme weather events
- To the Dutch professional societies of health professionals, the results of this thesis can be used for advocacy to strive for effective climate change mitigation measusres
- To the (global) research communities the effects of climate change in low-income countries should be more prioritized, including the effects of heat waves and pollution

The results of this thesis shall be shared with the Ministry of Health (MoH), in charge of health system related affairs and the Ministry of Forestry and Natural Resources, in charge of the climate change related affairs, UNICEF, the Dutch Society for Tropical Medicine & International Health and the Dutch Pediatric Society for advocacy purposes.

References

1. The United Nations. Convention on the Rights of the Child [Internet]. A/RES/44/25. 1989 [cited 2022 Jun 27]. p. 15. Available from: https://www.ohchr.org/sites/default/files/crc.pdf

2. Annex II Glossary AR5 IPCC [Internet]. 2014. Available from: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-AnnexII_FINAL.pdf

3. Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, De Souza Dias BF, et al. Safeguarding human health in the Anthropocene epoch: Report of the Rockefeller Foundation-Lancet Commission on planetary health. Lancet [Internet]. 2015;386(10007):1973–2028. Available from: http://dx.doi.org/10.1016/S0140-6736(15)60901-1

4. IPCC FAR WG III. Climate change: the IPCC response strategies. Clim Chang IPCC response Strateg [Internet]. 1990; Available from: https://www.ipcc.ch/report/ar1/wg3/

5. IPCC AR6 WG I. Climate Change 2021: The Physical Science Basis. Cambridge Univ Press [Internet]. 2021; Available from: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

6. IPCC AR6 WGII. IPCC AR6 Working Group II: Summary for policymakers: Climate Change 2022, Impacts, Adaptation and Vulnerability. 2022;7/35, B1. Available from: https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

7. Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, et al. A safe operating space for humanity. Nature. 2009;461(7263):472–5.

8. Edenhofer O, Pichs-Madruga R, Sokona Y, Farahani E, Kadner S, Seyboth K, et al. Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers. 2014.

9. Möller V, Diemen R van, Robin Matthews JB, Fuglestvedt JS, Méndez C, Reisinger A, et al. IPCC AR6 WG2 Annex II: Glossary. 2022; Available from: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf

10. Robinson M, Shine T. Achieving a climate justice pathway to 1.5 °C. Nat Clim Chang [Internet]. 2018;8(7):564–9. Available from: https://doi.org/10.1038/s41558-018-0189-7

11. Institute for European Environmental Policy - OXFAM. Carbon inequality in 2030 [Internet]. 2020. Available from: https://www.oxfam.org/en/research/carbon-inequality-2030

12. Helldén D, Andersson C, Nilsson M, Ebi KL, Friberg P, Alfvén T. Climate change and child health: a scoping review and an expanded conceptual framework. Lancet Planet Heal. 2021;5(3):e164–75.

13. WHO. Basic documents: forty-ninth edition (including amendments adopted up to 31 May 2019) [Internet]. Geneva: World Health Organization; 2020. 1/244. Available from: https://apps.who.int/gb/bd/

14. World Health Organization. Everybody's business - strengthening health systems to improve health outcomes : WHO's framework for action [Internet]. Geneva PP - Geneva: World Health Organization; 2007. Available from: https://apps.who.int/iris/handle/10665/43918

15. United Nations - General Assembly. Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development [Internet]. A/RES/71/313. 2017. Available from: https://digitallibrary.un.org/record/1291226?ln=en#record-files-collapse-header

16. WHO. Technical note: supplementary foods for the management of moderate acute malnutrition in infants and children 6-59 months of age [Internet]. Geneva; 2012. Available from: https://apps.who.int/iris/handle/10665/75836

17. Government of Malawi. Malawi State of Environment and Outlook Report [Internet]. 2010. 1–273 p. Available from: https://www.unep.org/resources/report/malawi-state-environment-and-outlook-report-0

18. WHO. Guideline: Updates on the management of severe acute malnutrition in infants and children [Internet]. Geneva; 2013. Available from: https://apps.who.int/iris/handle/10665/95584

19. World Commission on Environment and Development. Our Common Future ('The Brundtland Report') [Internet]. United Nations. 1987. Available from: https://digitallibrary.un.org/record/139811

20. United Nations. Transforming our world: The 2030 Agenda for sustainable development. A/RES/70/1. 2015;

21. Victora CG, Christian P, Vidaletti LP, Gatica-Domínguez G, Menon P, Black RE. Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. Lancet (London, England). 2021 Apr;397(10282):1388–99.

22. UN Water. What is Water security? Infographic [Internet]. 2013 [cited 2022 Jul 13]. Available from: https://www.unwater.org/publications/water-security-infographic/

23. Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, et al. Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. Lancet. 2009;373(9676):1693–733.

24. Declaration of the World Climate Conference. Environ Conserv [Internet]. 2009/08/24. 1979;6(2):137–8. Available from: doi: 10.1017/S0376892900002630

25. WMO, UNEP. Memorandum of understanding between the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) on the Intergovernmental Panel on Climate Change (IPCC) [Internet]. 1989 [cited 2022 Jun 9]. Available from: https://www.ipcc.ch/site/assets/uploads/2019/06/MOU_between_UNEP_and_WMO_on_IPCC-1989.pdf

26. The United Nations. United Nations Framework Convention on Climate Change (UNFCCC) agreement. 1992; Available from: https://www.un.org/en/conferences/environment/rio1992

27. IPCC TAR WGII. Chapter 9: Human Health [Internet]. 2001. Available from: https://www.ipcc.ch/report/ar3/wg2/

28. Neira M, Prüss-Ustün A. Preventing disease through healthy environments: A global assessment of the environmental burden of disease [Internet]. WHO, editor. WHO; 2016. 147 p. Available from: https://www.who.int/publications/i/item/9789241565196

29. Carlson CJ, Albery GF, Merow C, Trisos CH, Zipfel CM, Eskew EA, et al. Climate change increases cross-species viral transmission risk. Nature [Internet]. 2022; Available from: https://doi.org/10.1038/s41586-022-04788-w

30. Bunyavanich S, Landrigan CP, McMichael AJ, Epstein PR. The impact of climate change on child health. Ambul Pediatr. 2003;3(1):44–52.

31. The Lancet Public Health. COVID-19 pandemic: what's next for public health? Lancet Public Heal [Internet]. 2022;7(5):e391. Available from: https://www.sciencedirect.com/science/article/pii/S2468266722000950

32. World Health Organization. Coronavirus disease (COVID-19): Climate change [Internet]. 2020 [cited 2022 Aug 4]. Available from: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-climate-change

33. Ezzati M, Lopez AD, Rodgers A, Murray CJL. Comparative quantification of health risks : global and regional burden of disease attributable to selected major risk factors. WHO Library Cataloguing-in Publication Data. 2004.

34. WHO. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s [Internet]. 2014. Available from: https://www.who.int/publications/i/item/9789241507691

35. UNICEF. The climate crisis is a child rights crisis [Internet]. 2021. Available from: https://www.unicef.org/media/105376/file/UNICEF-climate-crisis-child-rights-crisis.pdf

36. RCPCH. The impact of climate change on child health - position statement [Internet]. 2021. Available from: https://www.rcpch.ac.uk/resources/impact-climate-change-global-child-health-position-statement

37. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet [Internet]. 2013;382(9890):427–51. Available from: https://www.sciencedirect.com/science/article/pii/S014067361360937X

38. WHO. Malnutrition [Internet]. 2022 [cited 2022 Jul 12]. Available from: https://www.who.int/health-topics/malnutrition#tab=tab_1

39. Barker DJP, Osmond C. Infant Mortality, Childhood Nutrition, and Ischaemic Heart Disease in England and Wales. Lancet. 1986;327(8489):1077–81.

40. Brenner BM, Garcia DL, Anderson S. Glomeruli and Blood Pressure: Less of One, More the Other? Am J Hypertens [Internet]. 1988 Oct 1;1(4_Pt_1):335–47. Available from: https://doi.org/10.1093/ajh/1.4.335

41. Rich-Edwards JW, Stampfer MJ, Manson JE, Rosner B, Hankinson SE, Colditz GA, et al. Birth weight and risk of cardiovascular disease in a cohort of women followed up since 1976. BMJ [Internet]. 1997 Aug 16;315(7105):396 LP – 400. Available from: http://www.bmj.com/content/315/7105/396.abstract

42. Roseboom T, de Rooij S, Painter R. The Dutch famine and its long-term consequences for adult health. Early Hum Dev. 2006;82(8):485–91.

43. Barker DJP, Osmond C, Forsén TJ, Kajantie E, Eriksson JG. Trajectories of Growth among Children Who Have Coronary Events as Adults. N Engl J Med [Internet]. 2005 Oct 27;353(17):1802–9. Available from: https://doi.org/10.1056/NEJMoa044160

44. Black MM, Walker SP, Fernald LCH, Andersen CT, DiGirolamo AM, Lu C, et al. Early childhood development coming of age: science through the life course. Lancet [Internet]. 2017 Jan 7;389(10064):77–90. Available from: https://doi.org/10.1016/S0140-6736(16)31389-7

45. WHO, Fund UNC, Group WB. Nurturing care for early childhood development: a framework for helping children survive and thrive to transform health and human

potential [Internet]. Geneva; 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/272604/WHO-FWC-MCA-18.02-eng.pdf

46. MapTiler Team. Coordinate Systems Worldwide [Internet]. WGS 84 / EPSG 4326. [cited 2022 Jul 26]. Available from: https://epsg.io/map#srs=4326&x=34.294553&y=-13.279956&z=7&layer=streets

47. Malawi. Malawi National Land Policy [Internet]. 2002. Available from: http://www.reforms.gov.mw/psrmu/sites/default/files/National Land Policy 2002.pdf

48. The World Bank. Malawi Systematic Country Diagnostic : Breaking the Cycle of Low Growth and Slow Poverty Reduction [Internet]. 2018. Available from: https://openknowledge.worldbank.org/handle/10986/31131

49. United Nations. Creation of the LDC category and timeline of changes to LDC membership and criteria [Internet]. [cited 2022 Aug 3]. Available from: https://www.un.org/development/desa/dpad/least-developed-country-category/creation-of-the-ldc-category-and-timeline-of-changes-to-ldc-membership-and-criteria.html

50. The World Bank. Historical classification by income [Internet]. 2021 [cited 2022 Apr 14]. Available from: http://databank.worldbank.org/data/download/site-content/OGHIST.xlsx

51. The World Bank. GNI per capita, Atlas method (current US$), Malawi [Internet]. 2020 [cited 2022 Apr 19]. Available from: https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=MW

52. The World Bank. GDP (currend USD) - Malawi [Internet]. 2021 [cited 2022 Jul 12]. Available from: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?loca-container=null&locations=MW

53. NSO Malawi. 2018 Malawi Population and Housing Census - Economic Characteristics of the Population Report [Internet]. 2020. Available from: http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2018/Thematic_Reports/Economic Characteristics of the Population Report.pdf

54. Malawi. Country information: The Republic of Malawi [Internet]. Government website. 2022 [cited 2022 May 25]. Available from: https://www.malawi.gov.mw

55. The World Bank. Malawi Country Environmental Analysis [Internet]. Malawi Country Environmental Analysis. 2019. Available from: https://openknowledge.worldbank.org/handle/10986/31326

56. United Nations. World Population Prospects 2019 [Internet]. 2019 [cited 2022 Jun 7]. Available from: https://population.un.org/%0Awpp/

57. Kanyuka M, Ndawala J, Mleme T, Chisesa L, Makwemba M, Amouzou A, et al. Malawi and Millennium Development Goal 4: a Countdown to 2015 country case study. Lancet Glob Heal [Internet]. 2016;4(3):e201–14. Available from: https://www.sciencedirect.com/science/article/pii/S2214109X15002946

58. United Nations. Implementation of the United Nations Millenium Declaration [Internet]. A/57/270. 2002 [cited 2022 Jun 1]. p. 35. Available from: https://www.un.org/millenniumgoals/sgreport2002.pdf?OpenElement

59. The World Bank. Mortality rate, under-5 (per 1000 live births) - Malawi [Internet]. 2020 [cited 2022 Apr 19]. Available from: https://data.worldbank.org/indicator/SH.DYN.MORT?locations=MW

60. Malawi G of. National Resilience Strategy - Breaking the Cycle of Food insecurity in Malawi [Internet]. 2019. Available from: https://drmims.sadc.int/en/documents/database/national-resilience-strategy-2018-2030-breaking-cycle-food-insecurity-malawi

61. Vaivada T, Akseer N, Akseer S, Somaskandan A, Stefopulos M, Bhutta ZA. Stunting in childhood: an overview of global burden, trends, determinants, and drivers of decline. Am J Clin Nutr [Internet]. 2020 Sep 14;112(Suppl 2):777S-791S. Available from: https://pubmed.ncbi.nlm.nih.gov/32860401

62. Government of Malawi - Department of Disaster Management Affairs. National Resilience Strategy (2018-2030) - Breaking the Cycle of Food Insecurity in Malawi. 2018.

63. The Humanitarian Data Exchange. Malawi - Health Indicators [Internet]. 2022 [cited 2022 Jun 1]. Available from: https://data.humdata.org/

64. UNICEF (Statistics and Monitoring Section). Technical Note, AARR of Underweight Prevalence. 2007;1–2.

65. WHO, UNICEF. The extension of the 2025 Maternal, Infant and Young Child nutrition targets to 2030 [Internet]. Discussion paper. 2019. Available from: https://apps.who.int/entity/nutrition/global-target-2025/discussion-paper-extension-targets-2030.pdf?ua=1

66. Harris C, Mills R, Seager E, Blackstock S, Hiwa T, Pumphrey J, et al. Paediatric deaths in a tertiary government hospital setting, Malawi. Paediatr Int Child Health [Internet]. 2019 Oct 2;39(4):240–8. Available from: https://doi.org/10.1080/20469047.2018.1536873

67. Seattle - United States: Institute for Health Metrics and Evaluation (IHME) - 2020. Global Burden of Disease Study 2019 (GBD 2019) Results [Internet]. 2019 [cited 2022 Jul 27]. Available from: https://vizhub.healthdata.org/gbd-results/

68. Malawi. Malawi NDC (Updated submission) [Internet]. 2021 [cited 2022 May 25]. Available from: https://www4.unfccc.int/sites/NDCStaging/Pages/Search.aspx?k=Malawi

69. Government of Malawi. Malawi 2019 Floods Post Disaster Needs Assessment Report [Internet]. 2019 [cited 2022 Jul 26]. Available from: https://reliefweb.int/report/malawi/malawi-2019-floods-post-disaster-needs-assessment-report

70. Tozier de la Poterie A, Arrighi J, Jjemba E. Preparing for the 2015-2016 El Niño: Humanitarian Action in Zambia, Somalia, Kenya, Ethiopia and Malawi. RCRC Clim Cent [Internet]. 2017;(October). Available from: https://reliefweb.int/report/kenya/preparing-2015-2016-el-ni-o-humanitarian-action-zambia-somalia-kenya-ethiopia-and

71. RCRC (Red Cross Climate Centre). Climate Profiles of Countries in Southern Africa : Malawi [Internet]. The Hague: RCRC; 2021. Available from: https://www.climatecentre.org/wp-content/uploads/Climate-Profiles-of-Countries-in-Southern-Africa-Malawi.pdf

72. IFRC Climate Centre. Climate Change Impacts on Health: Malawi Assessment [Internet]. 2021. Available from: https://www.climatecentre.org/wp-content/uploads/RCRC_IFRC-Country-assessments-MALAWI-3.pdf

73. WFP. Integrated Context Analysis (ICA) Malawi, 2014 - Technical Paper & Programmatic Recommendations [Internet]. [cited 2022 Jun 7]. Available from:

https://geonode.wfp.org/documents/6935

74. IPCC AR5 SYN SPM. AR5 Synthesis Report: Climate Change 2014. 2014;151. Available from: https://www.ipcc.ch/report/ar5/syr/

75. Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF. Present and future Köppen-Geiger climate classification maps at 1-km resolution. Sci Data [Internet]. 2018;5(1):180214. Available from: https://doi.org/10.1038/sdata.2018.214

76. Schwalm CR, Glendon S, Duffy PB. RCP8.5 tracks cumulative CO2 emissions. Proc Natl Acad Sci [Internet]. 2020 Aug 18;117(33):19656–7. Available from: https://doi.org/10.1073/pnas.2007117117

77. The United Nations. Paris agreement [Internet]. 2015. Available from: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

78. Friedlingstein P, Jones MW, O'Sullivan M, Andrew RM, Bakker DCE, Hauck J, et al. Global Carbon Budget 2021. Earth Syst Sci Data Discuss [Internet]. 2021 Nov 4;2021:1–191. Available from: https://essd.copernicus.org/preprints/essd-2021-386/essd-2021-386.pdf

79. Berry P, Campbell-Lendrum D, Corvalan C, Joy Guillemot. Protecting Health from Climate Change: Vulnerability and Adaptation Assesment. World Heal Organ [Internet]. 2013;62. Available from: http://apps.who.int/iris/bitstream/10665/104200/1/9789241564687_eng.pdf?ua=1

80. WHO regional office for Africa. Malawi reaffirms its commitment to climate action on World Health Day 2022 – Our Planet, Our Health [Internet]. 2022 [cited 2022 Jul 15]. Available from: https://www.afro.who.int/fr/node/16032

81. Ministry of Health - Malawi. Vulnerability and Adaptation Assessment of the Health Sector in Malawi to impacts of climate change. 2015;

82. Government of Malawi. Malawi's national adaptation programmes of action (NAPA). [Internet]. 2006. Available from: https://unfccc.int/resource/docs/napa/mwi01.pdf

83. Government of Malawi. Malawi National Adaptation Programmes of Action [Internet]. 2015. Available from: https://www.ead.gov.mw/storage/app/media/Resources/Miscellaneous/National Adaptation Programmes of Actions.pdf

84. Government of Malawi. Malawi's National Adaptation Plan Framework [Internet]. 2020. Available from: https://napglobalnetwork.org/resource/malawis-national-adaptation-plan-framework/

85. Government of Malawi. Malawi: National climate change management policy [Internet]. 2016. Available from: https://www.preventionweb.net/publication/malawi-national-climate-change-management-policy

86. UNFCCC. NDC Registry [Internet]. [cited 2022 Aug 4]. Available from: https://unfccc.int/NDCREG

87. Ritchie H, Roser M, Rosado P. CO_2 and Greenhouse Gas Emissions [Internet]. Our World in Data. 2020 [cited 2022 Apr 22]. Available from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

88. RIVM. Greenhouse gas emissions in the Netherlands 1990-2020, National Inventory Report 2022 [Internet]. 2022. Available from: https://www.rivm.nl/bibliotheek/rapporten/2022-0005.pdf

89. Data OW in. Greenhouse gas emmissions by sector, Malawi, 2018 [Internet]. 2018 [cited 2022 May 25]. Available from: https://ourworldindata.org/co2/country/malawi

90. Friedlingstein P, O'Sullivan M, Jones MW, Andrew RM, Hauck J, Olsen A, et al. Global Carbon Budget 2020. Earth Syst Sci Data [Internet]. 2020 Dec 11;12(4):3269–340. Available from: https://essd.copernicus.org/articles/12/3269/2020/

91. UNICEF. Making Climate and Environment Policies for & with Children and Young People [Internet]. 2021 [cited 2022 Jul 13]. p. 1–20. Available from: https://www.unicef.org/documents/child-sensitive-climate-environment-policies

92. Corporate Europe Observatory. Big Oil and Gas buying influence in Brussels [Internet]. 2019 [cited 2022 Jul 21]. Available from: https://corporateeurope.org/en/2019/10/big-oil-and-gas-buying-influence-brussels

93. Corporate Europe Observatory. Hundreds of fossil fuel lobbyists flooding COP26 climate talks [Internet]. 2021 [cited 2022 Jul 21]. Available from: https://corporateeurope.org/en/2021/11/hundreds-fossil-fuel-lobbyists-flooding-cop26-climate-talks

94. The Spectator - Brandon O'Neill. The heatwave green hysteria is out of control [Internet]. 2022 [cited 2022 Jul 21]. Available from: https://www.spectator.co.uk/article/the-heatwave-green-hysteria-is-out-of-control

95. DeSmog. Global Climate Coalition (GCC) [Internet]. [cited 2022 Jul 21]. Available from: https://www.desmog.com/global-climate-coalition/

96. The Guardian - Damian Carrington and Jelmer Mommers. 'Shell knew': oil giant's 1991 film warned of climate change danger [Internet]. 2017. Available from: https://web.archive.org/web/20170424174806/https://www.theguardian.com/environment/2017/feb/28/shell-knew-oil-giants-1991-film-warned-climate-change-danger

97. The Guardian - Suzanne Goldenberg. Exxon knew of climate change in 1981, email says – but it funded deniers for 27 more years [Internet]. 2015 [cited 2022 Jul 21]. Available from: https://web.archive.org/web/20151116155511/http://www.theguardian.com/environment/2015/jul/08/exxon-climate-change-1981-climate-denier-funding

98. The New York Times - Timothy Egan. Exxon Mobil and the G.O.P.: Fossil Fools [Internet]. 2015 [cited 2022 Jul 21]. Available from: https://web.archive.org/web/20210815075740/https://www.nytimes.com/2015/11/06/opinion/fossil-fools.html

99. Carl Sagan testifying before Congress in 1985 on climate change [Internet]. YouTube / C-SPAN. 1985 [cited 2022 Jul 21]. Available from: https://www.youtube.com/watch?v=Wp-WiNXH6hI&t=1s

100. Friedlingstein P, O'Sullivan M, Jones MW, Andrew RM, Hauck J OA et al. Global Carbon Budget 2020. Earth Syst Sci Data. 2020;Dec 11(12(4)):3269–340.

101. Kann D. US begins formal withdrawal from Paris climate accord [Internet]. CNN. 2019 [cited 2022 Aug 3]. Available from: https://edition.cnn.com/2019/11/04/politics/trump-formal-withdrawal-paris-climate-agreement/index.html

102. Abnett K. EU parliament backs labelling gas and nuclear investments as green [Internet]. Reuters. 2022 [cited 2022 Aug 3]. Available from: https://www.reuters.com/business/sustainable-business/eu-parliament-vote-green-gas-nuclear-rules-2022-07-06/

103. Gehrke L. Josep Borrell slammed for 'Greta syndrome' remark [Internet]. Politico.

2020 [cited 2022 Aug 3]. Available from: https://www.politico.eu/article/josep-borrell-slammed-for-greta-syndrome-remark/

104. World Health Organization. The World Health Report 2002: Reducing Risks, Promoting Healthy Life [Internet]. 2002. Available from: https://www.who.int/publications/i/item/9241562072

105. IFRC Climate Centre. Climate Change Impacts on Health and Livelihoods [Internet]. 2021. Available from: https://www.climatecentre.org/resources/publications/#Health and Livelihoods

106. Zangerl K, Kelman I. Assessment of Child Health in National Adaptation Programmes of Action for Climate Change. Prehosp Disaster Med [Internet]. 2017/04/20. 2017;32(S1):S157–S157. Available from: https://www.cambridge.org/core/article/assessment-of-child-health-in-national-adaptation-programmes-of-action-for-climate-change/CB2CCB7BF89E20440B96DD86313C9312

107. Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Belesova K, Berry H, et al. The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. Lancet. 2018;392(10163):2479–514.

108. DFID. Sustainable Livelihoods Guidance Sheets Introduction: Overview. Sustain Livelihoods Guid Sheets. 1999;

109. SADC. SADC Member states [Internet]. [cited 2022 Jul 13]. Available from: http://www.sadc.int/index.php/member-states

110. UN Statistics Division. Standard country or area codes for statistical use (M49) [Internet]. [cited 2022 Jul 13]. Available from: https://unstats.un.org/unsd/methodology/m49/

111. Mackenbach JP, van de Mheen H, Stronks K. A prospective cohort study investigating the explanation of socio-economic inequalities in health in the Netherlands. Soc Sci Med. 1994;38(2):299–308.

112. Dahlgren G, Whitehead M. Policies and strategies to promote social equity in health. Background document to WHO - Strategy paper for Europe. [Internet]. 1991. Available from: https://ideas.repec.org/p/hhs/ifswps/2007_014.html

113. Solar O, Irwin A. A conceptual framework for action on the social determinants of health. Social Determinants of Health Discussion Paper 2 (Policy and Practice). 2010; Available from: http://www.who.int/sdhconference/resources/ConceptualframeworkforactiononSDH_eng.pdf

114. The World Bank Group. Climate Change Knowledge Portal - Country Malawi - Vulnerability [Internet]. [cited 2022 Jul 15]. Available from: https://climateknowledgeportal.worldbank.org/country/malawi/vulnerability

115. Suarez, P., Givah, P., Storey, K., & Lotsch A. HIV / AIDS , Climate Change and Disaster Management: Challenges for Institutions in Malawi. 2008;(May):1–37.

116. Baquie S, Fuje H. Vulnerability to Poverty following Extreme Weather Events in Malawi [Internet]. 2020. Available from: https://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-9435

117. Government of Malawi - Ministry of Forestry and Natural Resources. The Third National Communication of the Republic of Malawi to the COP of the UNFCCC [Internet]. 2021. Available from: https://unfccc.int/documents/268340

118. Van Aalst MK. The impacts of climate change on the risk of natural disasters. Disasters [Internet]. 2006 Mar 1;30(1):5–18. Available from: https://doi.org/10.1111/j.1467-9523.2006.00303.x

119. Ummenhofer CC, Meehl GA. Extreme weather and climate events with ecological relevance: A review. Vol. 372, Philosophical Transactions of the Royal Society B: Biological Sciences. Royal Society Publishing; 2017.

120. McCarthy N, Kilic T, de la Fuente A, Brubaker J. Shelter from the Storm? Household-Level Impacts of, and Responses to, the 2015 Floods in Malawi [Internet]. 2017. Available from: https://openknowledge.worldbank.org/handle/10986/28366

121. Bakshi B, Nawrotzki RJ, Donato JR, Lelis LS. Exploring the link between climate variability and mortality in Sub-Saharan Africa. Int J Environ Sustain Dev. 2019;18(2):206–37.

122. Cai W, Borlace S, Lengaigne M, van Rensch P, Collins M, Vecchi G, et al. Increasing frequency of extreme El Niño events due to greenhouse warming. Nat Clim Chang [Internet]. 2014;4(2):111–6. Available from: https://doi.org/10.1038/nclimate2100

123. The World Bank. Malawi Poverty and Vulnerability Assessment: Investing in Our Future, synthesis report [Internet]. 2007. Available from: https://openknowledge.worldbank.org/handle/10986/7557

124. Government of Malawi. Malawi 2015 Floods Post Disaster Needs Assessment Report [Internet]. 2015. Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/Malawi-2015-Floods-Post-Disaster-Needs-Assessment-Report.pdf

125. Vincent K, Dougill AJ, Mkwambisi D, Cull T, Stringer LC, Chanika D. Analysis of Existing Weather and Climate Information for Malawi. In 2014. Available from: https://www.futureclimateafrica.org/wp-content/uploads/2015/02/Malawi-existing-Analysis-of-existing-weather-and-climate-information-for-Malawi-final-with-disclaimer.pdf

126. Mittal N, Vincent K, Conway D, Archer can Garderen E, Pardoe J, Todd M, et al. Future climate projections for Malawi. Futur Clim Africa Ctry Clim Brief [Internet]. 2017;(October). Available from: https://www.futureclimateafrica.org/wp-content/uploads/2017/10/2772_malawi_climatebrief_v6.pdf

127. Glenn BE, Espira LM, Larson MC, Larson PS. Ambient air pollution and non-communicable respiratory illness in sub-Saharan Africa: a systematic review of the literature. Environ Heal A Glob Access Sci Source. 2022 Dec 1;21(1).

128. Stevens T, Madani K. Future climate impacts on maize farming and food security in Malawi. Sci Rep [Internet]. 2016;6(1):36241. Available from: https://doi.org/10.1038/srep36241

129. Future Climate For Africa. Brief: Future climate projections for Malawi - Annex [Internet]. 2017 [cited 2022 Jul 29]. Available from: https://futureclimateafrica.org/resource/future-climate-projections-for-malawi/

130. The World Bank. Climate Change Knowledge Portal - Country Malawi - Sea Level Rise [Internet]. [cited 2022 Aug 4]. Available from: https://climateknowledgeportal.worldbank.org/country/malawi/impacts-sea-level-rise

131. Cohen AS, Gergurich EL, Kraemer BM, McGlue MM, McIntyre PB, Russell JM, et al. Climate warming reduces fish production and benthic habitat in Lake Tanganyika, one of the most biodiverse freshwater ecosystems. Proc Natl Acad Sci U S A [Internet]. 2016 Jul 22;113(34):9563–8. Available from: https://www-jstor-org.vu-

nl.idm.oclc.org/stable/26471497

132. Jørstad H, Webersik C. Vulnerability to climate change and adaptation strategies of local communities in Malawi: experiences of women fish-processing groups in the Lake Chilwa Basin. Earth Syst Dynam [Internet]. 2016 Dec 21;7(4):977–89. Available from: https://esd.copernicus.org/articles/7/977/2016/

133. Otto FEL, Zachariah M, Wolski P, Pinto I, Barimalala R, Nhamtumbo B, et al. Climate change increased rainfall associated with tropical cyclones hitting highly vulnerable communities in Madagascar, Mozambique & Malawi. 2022;(February). Available from: https://www.worldweatherattribution.org/climate-change-increased-rainfall-associated-with-tropical-cyclones-hitting-highly-vulnerable-communities-in-madagascar-mozambique-malawi/

134. UNICEF Malawi. Annual Report 2019 [Internet]. 2019. Available from: https://www.unicef.org/malawi/reports/unicef-malawi-annual-report-2019

135. SADC Regional Vulnerability Assessment & Analysis RVAA. Synthesis report: on the state of Food and Nutrition Security and Vulnerability in Southern Africa [Internet]. 2018. Available from: https://reliefweb.int/report/democratic-republic-congo/sadc-regional-vulnerability-assessment-analysis-rvaa-synthesis

136. Baez JE, Kshirsagar V, Skoufias E. Adaptive Safety Nets for Rural Africa: Drought-Sensitive Targeting with Sparse Data [Internet]. 2019. Available from: https://openknowledge.worldbank.org/handle/10986/33014

137. The World Bank. Early Childhood Development: Situational Analysis for Malawi [Internet]. 2016. Available from: https://openknowledge.worldbank.org/handle/10986/24574

138. UNICEF Malawi. The Child Marriage Factsheet. 2017.

139. UNICEF. Unless we act now - the impact of climate change on children [Internet]. 2015. Available from: https://www.unicef.org/reports/unless-we-act-now-impact-climate-change-children

140. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature [Internet]. 2005;438(7066):310–7. Available from: https://doi.org/10.1038/nature04188

141. Olwoch J, Reyers B, Engelbrecht F, Erasmus B. Climate change and the tick-borne disease, Theileriosis (East Coast fever) in sub-Saharan Africa. J Arid Environ. 2008 Feb 1;72:108–20.

142. Bouma M, van der Kaay H. Epidemic malaria in India and the El Niño Southern Oscillation. Lancet [Internet]. 1994;344(8937):1638–9. Available from: https://www.sciencedirect.com/science/article/pii/S0140673694904324

143. Lindblade KA, Walker ED, Onapa AW, Katungu J, Wilson ML. Highland malaria in Uganda: prospective analysis of an epidemic associated with El Niño. Trans R Soc Trop Med Hyg [Internet]. 1999;93(5):480–7. Available from: https://www.sciencedirect.com/science/article/pii/S0035920399903449

144. Schraufnagel DE, Balmes JR, Cowl CT, De Matteis S, Jung S-H, Mortimer K, et al. Air Pollution and Noncommunicable Diseases: A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution. Chest [Internet]. 2019;155(2):409–16. Available from: http://europepmc.org/abstract/MED/30419235

145. Nolte CG, Spero TL, Bowden JH, Sarofim MC, Martinich J, Mallard MS. Regional

temperature-ozone relationships across the U.S. under multiple climate and emissions scenarios. J Air Waste Manage Assoc [Internet]. 2021 Oct 3;71(10):1251–64. Available from: https://doi.org/10.1080/10962247.2021.1970048

146. Philipsborn RP, Chan K. Climate change and global child health. Pediatrics. 2018;141(6).

147. Smith CJ. Pediatric thermoregulation: Considerations in the face of global climate change. Nutrients. 2019;11(9):15–8.

148. Denning G, Kabambe P, Sanchez P, Malik A, Flor R, Harawa R, et al. Input Subsidies to Improve Smallholder Maize Productivity in Malawi: Toward an African Green Revolution. PLOS Biol [Internet]. 2009 Jan 27;7(1):e1000023. Available from: https://doi.org/10.1371/journal.pbio.1000023

149. Government of Malawi - Ministry of Agriculture. 2018/2019 FISP Implementation Guidelines [Internet]. [cited 2022 Aug 6]. Available from: https://agriculture.gov.mw/index.php/projects/fisp

150. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, et al. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. Annu Rev Public Health [Internet]. 2017 Mar 20;38(1):259–77. Available from: https://doi.org/10.1146/annurev-publhealth-031816-044356

151. Kafumbata D, Jamu D, Chiotha S. Riparian ecosystem resilience and livelihood strategies under test: lessons from Lake Chilwa in Malawi and other lakes in Africa. Philos Trans R Soc B Biol Sci [Internet]. 2014 Apr 5;369(1639):20130052. Available from: https://doi.org/10.1098/rstb.2013.0052

152. Ngwira A. Shared geographic spatial risk of childhood undernutrition in Malawi: An application of joint spatial component model. Public Heal Pract [Internet]. 2022;3:100224. Available from: https://www.sciencedirect.com/science/article/pii/S266653522100149X

153. Benson T. Disentangling food security from subsistence agriculture in Malawi [Internet]. Washington, DC; 2021. Available from: https://www.ifpri.org/publication/disentangling-food-security-subsistence-agriculture-malawi

154. McCarthy N, Kilic T, Brubaker J, Murray S, de la Fuente A. Droughts and floods in Malawi: impacts on crop production and the performance of sustainable land management practices under weather extremes. Environ Dev Econ [Internet]. 2021/01/25. 2021 Oct 25;26(5–6):432–49. Available from: https://www.cambridge.org/core/product/identifier/S1355770X20000455/type/journal_article

155. Randell H, Gray C. Climate change and educational attainment in the global tropics. Proc Natl Acad Sci [Internet]. 2019 Apr 30;116(18):8840–5. Available from: https://doi.org/10.1073/pnas.1817480116

156. HDX. Malawi - Internally displaced persons - IPDs [Internet]. [cited 2022 Aug 6]. Available from: https://data.humdata.org/dataset/idmc-idp-data-for-malawi

157. Wall EC, Everett DB, Mukaka M, Bar-Zeev N, Feasey N, Jahn A, et al. Bacterial Meningitis in Malawian Adults, Adolescents, and Children During the Era of Antiretroviral Scale-up and Haemophilus influenzae Type b Vaccination, 2000–2012. Clin Infect Dis [Internet]. 2014 May 15;58(10):e137–45. Available from: https://doi.org/10.1093/cid/ciu057

158. United Nations - Malawi - Reliefweb. Malawi: Tropical Storm Ana Response flash

update no. 3, 16th February 2022. 2022;(3):1–9. Available from: https://reliefweb.int/report/malawi/malawi-tropical-storm-ana-response-flash-update-no-3-16th-february-2022

159. Nagata JM, Epstein A, Ganson KT, Benmarhnia T, Weiser SD. Drought and child vaccination coverage in 22 countries in sub-Saharan Africa: A retrospective analysis of national survey data from 2011 to 2019. PLOS Med [Internet]. 2021 Sep 28;18(9):e1003678. Available from: https://doi.org/10.1371/journal.pmed.1003678

160. WHO regional office for Africa. Malawi declares polio outbreak [Internet]. 2022 [cited 2022 Jul 15]. Available from: https://www.afro.who.int/news/malawi-declares-polio-outbreak

161. Government of Malawi - Ministry of Health. Health Sector Strategic Plan II 2017-2022 - Towards Universal Health Coverage [Internet]. 2017. Available from: http://www.health.gov.mw/index.php/policies-strategies#

162. Government of Malawi. Malaria - Ministry of Health [Internet]. [cited 2022 Jul 26]. Available from: http://www.health.gov.mw/index.php/malaria

163. World Health Organization. Increasing equity to malaria prevention through vaccination pilot in Malawi [Internet]. 2021 [cited 2022 Aug 2]. Available from: https://www.who.int/news-room/feature-stories/detail/increasing-equity-to-malaria-prevention-through-vaccination-pilot-in-malawi

164. Eltom K, Enan K, El Hussein ARM, Elkhidir IM. Dengue Virus Infection in Sub-Saharan Africa Between 2010 and 2020: A Systematic Review and Meta-Analysis. Front Cell Infect Microbiol [Internet]. 2021;11. Available from: https://www.frontiersin.org/articles/10.3389/fcimb.2021.678945

165. Adam A, Jassoy C. Epidemiology and Laboratory Diagnostics of Dengue, Yellow Fever, Zika, and Chikungunya Virus Infections in Africa. Vol. 10, Pathogens . 2021.

166. Xu Z, Sheffield PE, Hu W, Su H, Yu W, Qi X, et al. Climate Change and Children's Health—A Call for Research on What Works to Protect Children. Vol. 9, International Journal of Environmental Research and Public Health . 2012. p. 3298–316.

167. Lord JS. Changes in Rice and Livestock Production and the Potential Emergence of Japanese Encephalitis in Africa. Pathogens 2021, 10, 294. Pathogens. 2021;

168. Madsen H, Stauffer JR. Schistosomiasis Control Under Changing Ecological Settings in Lake Malawi. Ecohealth [Internet]. 2022; Available from: https://doi.org/10.1007/s10393-022-01606-7

169. National Statistical Office. Malawi - Multiple Indicator Cluster Survey 2019-20 [Internet]. 2021. Available from: www.nsomalawi.mw

170. Rivett MO, Tremblay-Levesque L-C, Carter R, Thetard RCH, Tengatenga M, Phoya A, et al. Acute health risks to community hand-pumped groundwater supplies following Cyclone Idai flooding. Sci Total Environ [Internet]. 2022;806:150598. Available from: https://www.sciencedirect.com/science/article/pii/S004896972105676X

171. Checkley W, Epstein LD, Gilman RH, Figueroa D, Cama RI, Patz JA, et al. Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. Lancet [Internet]. 2000 Feb 5;355(9202):442–50. Available from: https://doi.org/10.1016/S0140-6736(00)82010-3

172. Nhung NTT, Amini H, Schindler C, Kutlar Joss M, Dien TM, Probst-Hensch N, et al. Short-term association between ambient air pollution and pneumonia in children: A

systematic review and meta-analysis of time-series and case-crossover studies. Environ Pollut. 2017 Nov;230:1000–8.

173. Zar HJ, Madhi SA, Aston SJ, Gordon SB. Pneumonia in low and middle income countries: progress and challenges. Thorax. 2013 Nov;68(11):1052–6.

174. National Statistical Office. Malawi Poverty Report 2020. 2019;(August):1–36. Available from: https://microdata.worldbank.org/index.php/catalog/3818/download/51154

175. Republic of Malawi. Malawi National Social Support Programme II (MNSSP II). 2018;(March):2018–23. Available from: https://socialprotection.org/discover/legal_policy_frameworks/malawi-national-social-support-programme-mnssp-ii

176. IPCC AR6 WGIII SPM. Climate Change 2022 - Mitigation of Climate Change - Summary for Policymakers (SPM). Cambridge University Press. 2022. 1–30 p.

177. McFarlane D, Abramson E. Carbon Budget 101: What It Is and Why It Matters [Internet]. Great Plains Institute. 2021 [cited 2022 Aug 3]. Available from: https://betterenergy.org/blog/carbon-budget-101-what-it-is-and-why-it-matters/

178. National Statistical Office. Malawi Multiple Indicator Cluster Survey 2019-20, Survey Findings Report. [Internet]. Zomba, Malawi; 2021. Available from: https://www.unicef.org/malawi/reports/malawi-multiple-indicator-cluster-survey-report

179. The World Bank. The World Bank - Data [Internet]. 2020 [cited 2022 Jun 2]. Available from: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=MW

180. The World Bank - IMF - IDA. Joint World Bank-IMF Debt Sustainability Analysis [Internet]. 2020. Available from: http://documents.worldbank.org/curated/en/807901607563376948/pdf/Malawi-Joint-World-Bank-IMF-Debt-Sustainability-Analysis.pdf

181. Government of Malawi. Malawi Health Workforce Observatory - HRH Country Profile Malawi. 2010;

182. Quattrochi JP, Hill K, Salomon JA, Castro MC. The effects of changes in distance to nearest health facility on under-5 mortality and health care utilization in rural Malawi, 1980-1998. BMC Health Serv Res. 2020;20(1):899.

183. World Health Organization. World health statistics 2022 (Monitoring health of the SDGs) [Internet]. 2022. Available from: https://www.who.int/data/gho/publications/world-health-statistics

184. World Health Organization - Global Health Workforce Statistics. National Health Workforce Accounts - Data portal [Internet]. 2021 [cited 2022 Aug 1]. Available from: https://apps.who.int/nhwaportal/Home/Index

185. World Health Organization. Global strategy on human resources for health: Workforce 2030. 2016;64. Available from: https://www.who.int/hrh/resources/global_strategy_workforce2030_14_print.pdf?ua=1

186. National Statistical Office. Malawi MICS 2019-20, Snapshots of Key Findings. 2021; Available from: https://www.unicef.org/malawi/reports/malawi-multiple-indicator-cluster-survey-report

187. Minetti A, Kagoli M, Katsulukuta A, Huerga H, Featherstone A, Chiotcha H, et al. Lessons and challenges for measles control from unexpected large outbreak, Malawi. Emerg Infect Dis [Internet]. 2013;19(2):202–9. Available from:

http://europepmc.org/abstract/MED/23343504

188. Malawi G of. Malawi's Vision - An Inclusively Wealthy and Self-reliant Nation - Malawi 2063 [Internet]. 2020. Available from: https://malawi.un.org/en/108390-malawi-vision-2063-inclusively-wealthy-and-self-reliant-nation

189. World Population Review. HIV Prevalence rates by country 2022 [Internet]. 2020 [cited 2022 Jul 20]. Available from: http://worldpopulationreview.com/country-rankings/hiv-rates-by-country

190. UNICEF. Child poverty [Internet]. [cited 2022 Aug 8]. Available from: https://www.unicef.org/social-policy/child-poverty

191. International Monetary Fund. Malawi: Debt Relief at the Heavily Indebted Poor Countries Initiative Completion Point and Under the Multilateral Debt Relief Initiative. IMF Staff Ctry Reports. 2006;06(420):1.

192. Govenment of Malawi - Ministry of Finance Economic Planning and Development. Annual Economic Report 2019. Dep Econ Plan Dev [Internet]. 2019; Available from: https://www.finance.gov.mw/index.php/our-documents/annual-economic-reports?download=68:2019-annual-economic-report

193. Lencucha R, Moyo T, Labonte R, Drope J, Appau A, Makoka D. Shifting from tobacco growing to alternatives in Malawi? A qualitative analysis of policy and perspectives. Health Policy Plan [Internet]. 2020 Aug 1;35(7):810–8. Available from: https://pubmed.ncbi.nlm.nih.gov/32525201

194. Jones A. Malnutrition, Poverty, and Climate Change are also Human Rights Issues in Child Labor. Health Hum Rights. 2018 Dec;20(2):249–51.

195. National Statistical Office (NSO) and ICF. 2015-2016 Malawi DHS Key Findings. 2017;20.

196. Hochrainer S, Mechler R, Pflug G, Lotsch A. Investigating the Impact of Climate Change on the Robustness of Index-based Microinsurance in Malawi. 2008;(May):1–25.

197. IPCC AR4 WGI Technical Summary. Climate change 2007: The Physical science basis. 2007; Available from: https://www.ipcc.ch/report/ar4/wg1/

198. Williams JN, Mdala H, Fagereng Å, Wedmore LNJ, Biggs J, Dulanya Z, et al. A systems-based approach to parameterise seismic hazard in regions with little historical or instrumental seismicity: active fault and seismogenic source databases for southern Malawi. Solid Earth [Internet]. 2021 Jan 27 [cited 2022 Jul 19];12(1):187–217. Available from: https://se.copernicus.org/articles/12/187/2021/

199. Intergovernmental Panel on Climate Change (IPCC), editor. Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: The Ocean and Cryosphere in a Changing Climate: Special Report of the Intergovernmental Panel on Climate Change [Internet]. Cambridge: Cambridge University Press; 2022. p. 321–446. Available from: https://www.cambridge.org/core/books/ocean-and-cryosphere-in-a-changing-climate/sea-level-rise-and-implications-for-lowlying-islands-coasts-and-communities/5D756335C9C3A6DDFAE0219073349E8D

200. Worldatlas. Maps Of Malawi [Internet]. [cited 2022 Jul 29]. Available from: https://www.worldatlas.com/maps/malawi

201. Landrigan PJ, Stegeman JJ, Fleming LE, Allemand D, Anderson DM, Backer LC, et al. Human Health and Ocean Pollution. Ann Glob Heal. 2020 Dec;86(1):151.

202. Su WH, Shi W, Han Y, Hu Y, Ke AY, Wu HX, et al. The health risk for seafood consumers under future ocean acidification (OA) scenarios: OA alters bioaccumulation of three pollutants in an edible bivalve species through affecting the in vivo metabolism. Sci Total Environ. 2019;650:2987–95.

203. Hajat S, Armstrong BG, Gouveia N, Wilkinson P. Mortality Displacement of Heat-Related Deaths: A Comparison of Delhi, São Paulo, and London. Epidemiology [Internet]. 2005;16(5). Available from: https://journals.lww.com/epidem/Fulltext/2005/09000/Mortality_Displacement_of_Heat_Related_Deaths__A.4.aspx

204. Yamauchi F, Yohannes Y, Quisumbing AR. Risks, ex-ante actions, and public assistance: Impacts of natural disasters on child schooling in Bangladesh, Ethiopia, and Malawi. IFPRI Discuss Pap [Internet]. 2009;880(April):29. Available from: https://openknowledge.worldbank.org/handle/10986/4103

205. Goodman J, Hurwitz M, Park J, Smith J. Heat and Learning. Natl Bur Econ Res Work Pap Ser [Internet]. 2018;No. 24639. Available from: http://www.nber.org/papers/w24639

206. Anderko L, Chalupka S, Du M, Hauptman M. Climate changes reproductive and children's health: a review of risks, exposures, and impacts. Pediatr Res [Internet]. 2020;87(2):414–9. Available from: http://dx.doi.org/10.1038/s41390-019-0654-7

207. ITU - Telecommunication Development Sector. Developing an E-waste National Policy and regulatory framework for Malawi [Internet]. 2018. Available from: https://www.itu.int/en/ITU-D/Climate-Change/Documents/2018/Developing_e-waste_national_policy_and_regulatory_framework_Malawi.pdf

208. Kidd KA, Bootsma HA, Hesslein RH, Lyle Lockhart W, Hecky RE. Mercury Concentrations in the Food Web of Lake Malawi, East Africa. J Great Lakes Res [Internet]. 2003;29:258–66. Available from: https://www.sciencedirect.com/science/article/pii/S038013300370553X

209. Famine Early Warning System Network. Malawi Food Security Outlook Update April 2022 [Internet]. 2022. Available from: https://reliefweb.int/report/malawi/malawi-food-security-outlook-update-april-2022

210. Rother H-A, Hayward RA, Paulson JA, Etzel RA, Shelton M, Theron LC. Impact of extreme weather events on Sub-Saharan African child and adolescent mental health: The implications of a systematic review of sparse research findings☆. J Clim Chang Heal [Internet]. 2022;5:100087. Available from: https://www.sciencedirect.com/science/article/pii/S2667278221000845

211. Reliefweb. Malawi, Africa | Tropical Storm Ana 2022 - Emergency Appeal n° MDRMW015 [Internet]. 2022 [cited 2022 Jul 21]. Available from: https://reliefweb.int/report/malawi/malawi-africa-tropical-storm-ana-2022-emergency-appeal-n-mdrmw015

212. Garlick PJ. Protein Requirements of Infants and Children. In: Nestlé Nutrition Institute Workshop Series [Internet]. 2006. p. 39–50. Available from: https://www.karger.com/DOI/10.1159/000095009

213. SACN. Dietary Reference Values for Energy 2011 [Internet]. Dietary Reference Values for Energy. 2011. 225 p. Available from: www.sacn.gov.uk

214. Alan Buis - NASA. Steamy Relationships: How Atmospheric Water Vapor Supercharges Earth's Greenhouse Effect [Internet]. 2022 [cited 2022 Jul 25]. Available from: https://climate.nasa.gov/ask-nasa-climate/3143/steamy-relationships-

how-atmospheric-water-vapor-supercharges-earths-greenhouse-effect/

215. Wikipedia. Latent heat [Internet]. [cited 2022 Jul 26]. Available from: https://en.wikipedia.org/wiki/Latent_heat

216. WMO. El Niño / Southern Oscillation [Internet]. 2014. Available from: https://library.wmo.int/index.php?lvl=notice_display&id=16747

217. Red Cross Red Crescent Climate Center. The added value of Red Cross Red Crescent National Societies in the development of National Adaptation Plans. 2016; Available from: https://www.climatecentre.org/downloads/files/RCCC_WCS_magazine V3 web.pdf

218. Herrera D, Ellis A, Fisher B, Golden CD, Johnson K, Mulligan M, et al. Upstream watershed condition predicts rural children's health across 35 developing countries. Nat Commun [Internet]. 2017;8(1):811. Available from: https://doi.org/10.1038/s41467-017-00775-2

219. Ardrey J, Jehan K, Desmond N, Kumbuyo C, Mortimer K, Tolhurst R. "Cooking is for everyone?": Exploring the complexity of gendered dynamics in a cookstove intervention study in rural Malawi. Glob Health Action. 2021 Dec;14(1):2006425.

220. Mortimer K, Ndamala CB, Naunje AW, Malava J, Katundu C, Weston W, et al. A cleaner burning biomass-fuelled cookstove intervention to prevent pneumonia in children under 5 years old in rural Malawi (the Cooking and Pneumonia Study): a cluster randomised controlled trial. Lancet [Internet]. 2017 Jan 14;389(10065):167–75. Available from: https://doi.org/10.1016/S0140-6736(16)32507-7

Annexes

Annex 1: Figures

Figure 1: Children caught in a vicious cycle of increasing exposures and vulnerabilities face an increase in their overall level of risk (35)

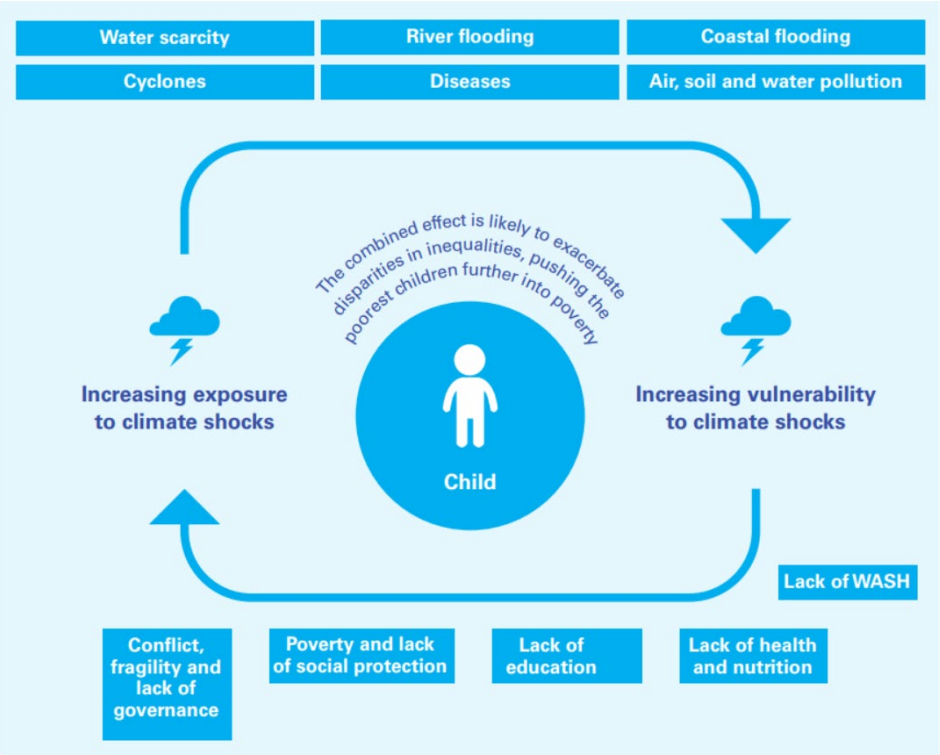


Figure 2: CCRI conceptual model: pillars and components (35)

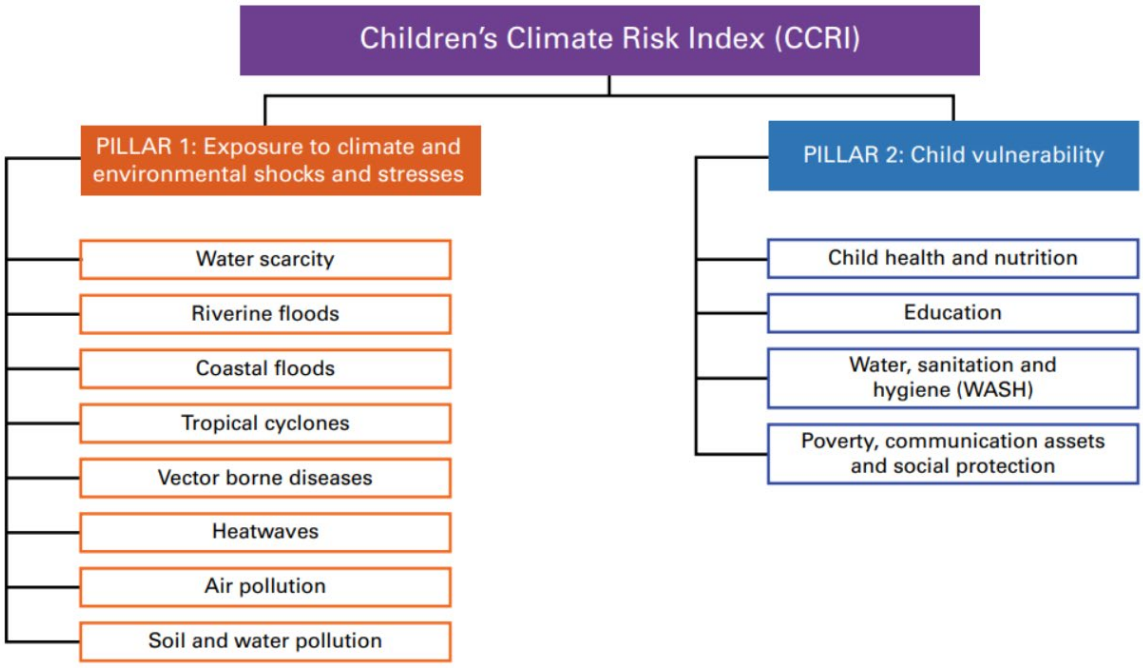
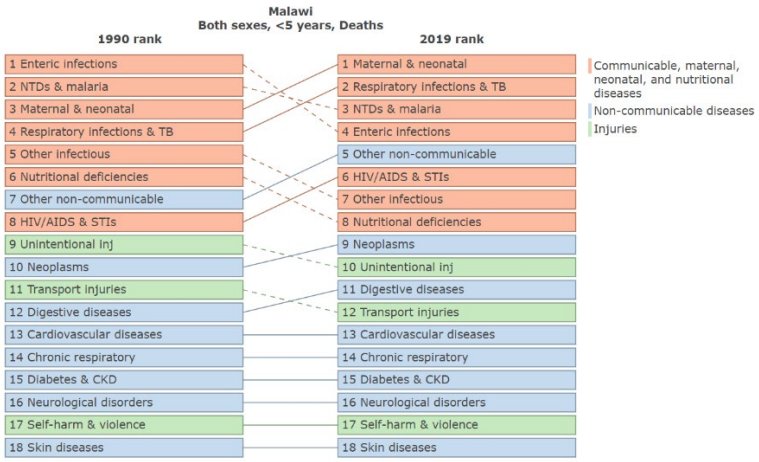


Figure 3: Cause of under 5 deaths 1990 vs 2019 Malawi, both sexes



Source: IHME Global Burden of Disease 2019 (67)

Figure 4: Recurrence of food insecure populations > 30% (2009-2013 WFP/IHS) (73)

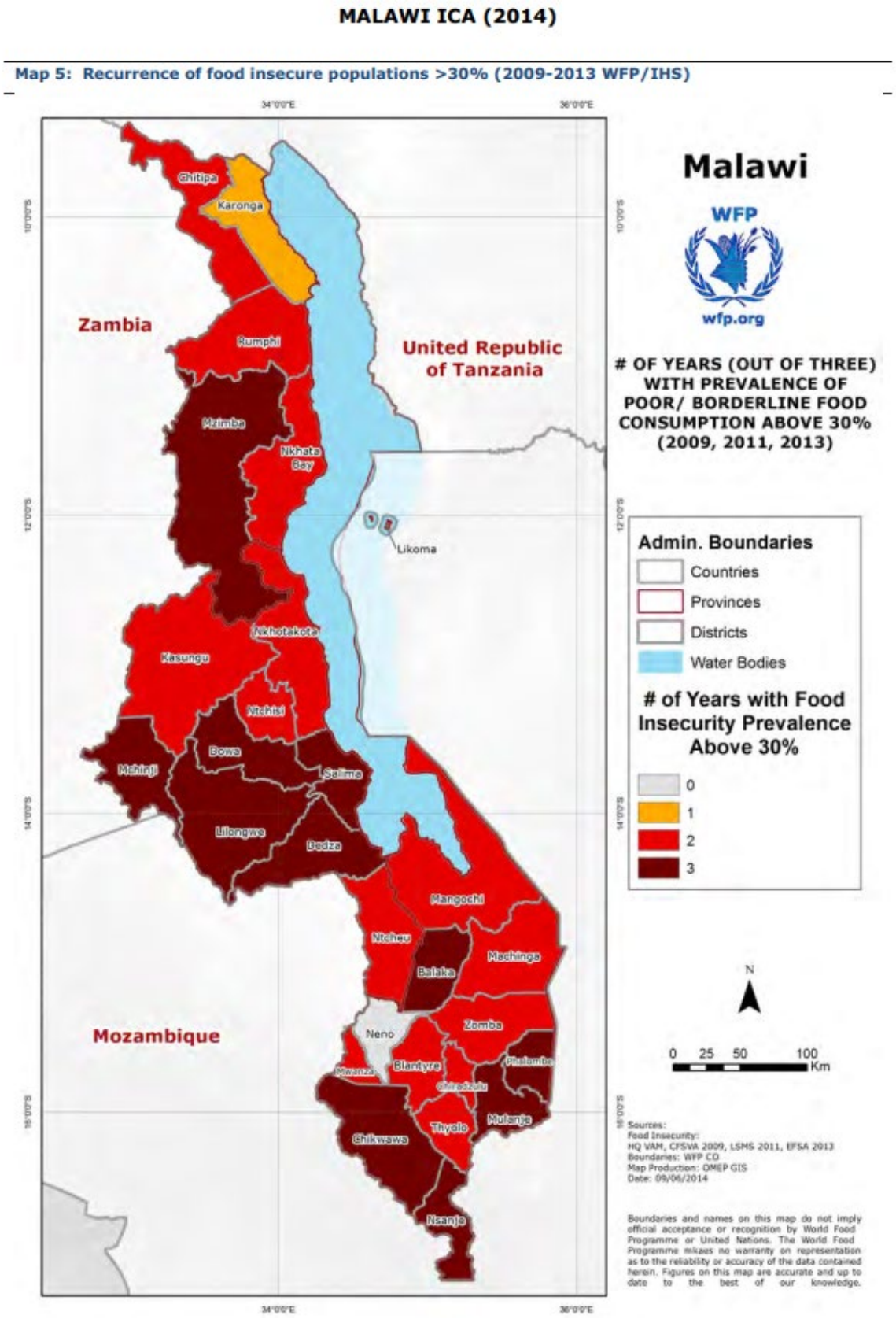


Figure 5: Malawi ICA 2014, combined drought and flood risk by district (73)

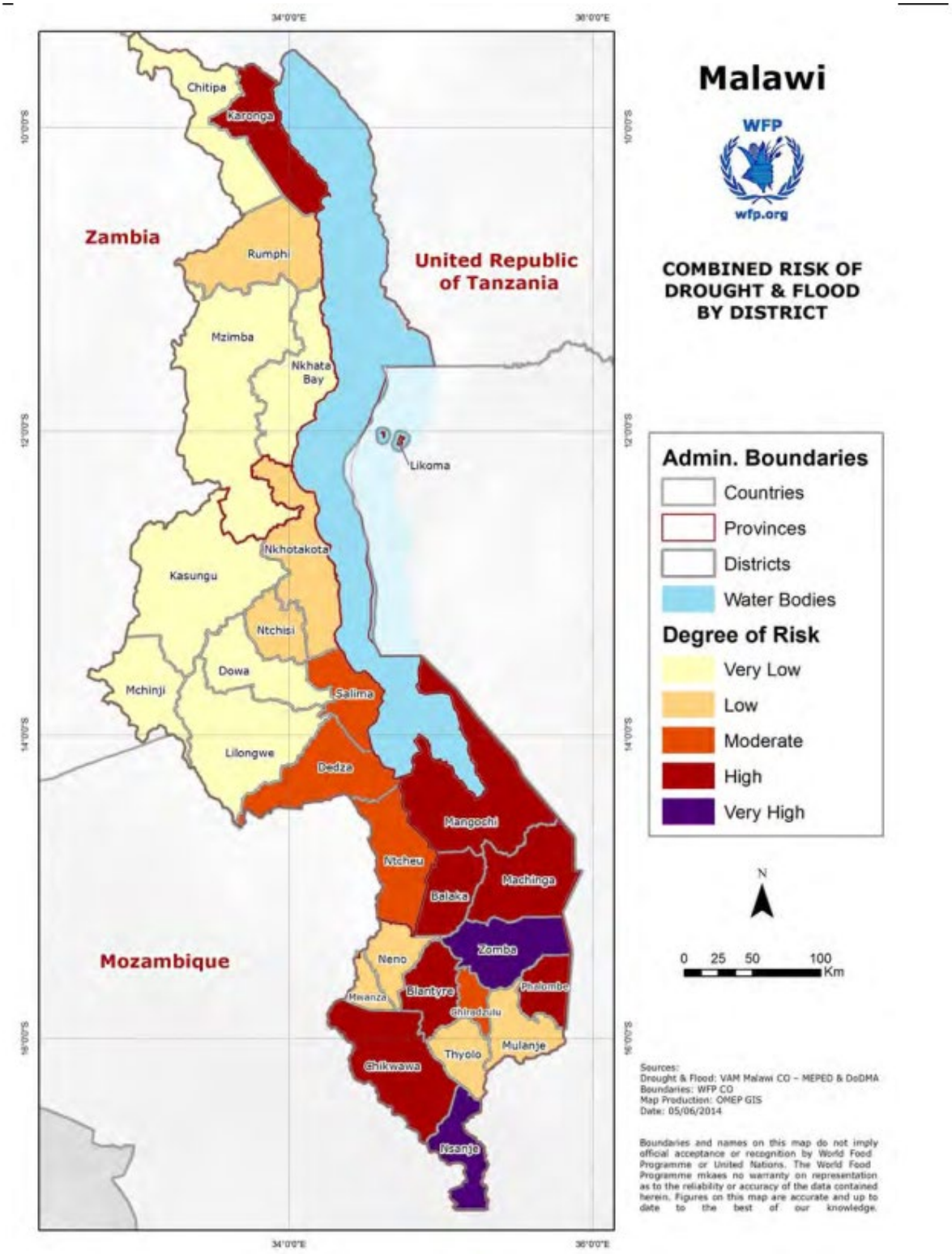


Figure 6: AR5 Synthesis report SPM (74)

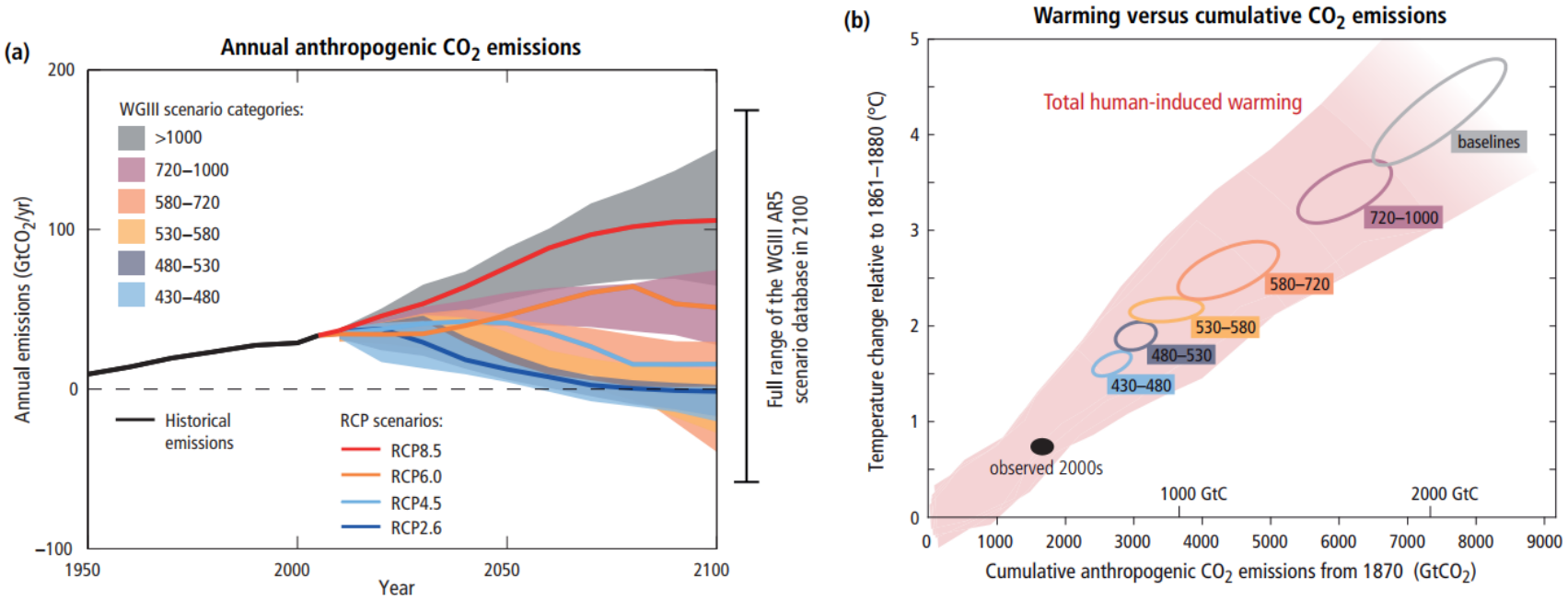


Figure SPM.5 | (a) Emissions of carbon dioxide (CO_2) alone in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in WGIII (coloured areas show 5 to 95% range). The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-eq concentration levels (in ppm) in 2100. The time series of other greenhouse gas emissions are shown in Box 2.2, Figure 1. **(b)** Global mean surface temperature increase at the time global CO_2 emissions reach a given net cumulative total, plotted as a function of that total, from various lines of evidence. Coloured plume shows the spread of past and future projections from a hierarchy of climate-carbon cycle models driven by historical emissions and the four RCPs over all times out to 2100, and fades with the decreasing number of available models. Ellipses show total anthropogenic warming in 2100 versus cumulative CO_2 emissions from 1870 to 2100 from a simple climate model (median climate response) under the scenario categories used in WGIII. The width of the ellipses in terms of temperature is caused by the impact of different scenarios for non-CO_2 climate drivers. The filled black ellipse shows observed emissions to 2005 and observed temperatures in the decade 2000–2009 with associated uncertainties. *{Box 2.2, Figure 1; Figure 2.3}*

Figure 7: Expected change in climate Malawi under RCP 8.5

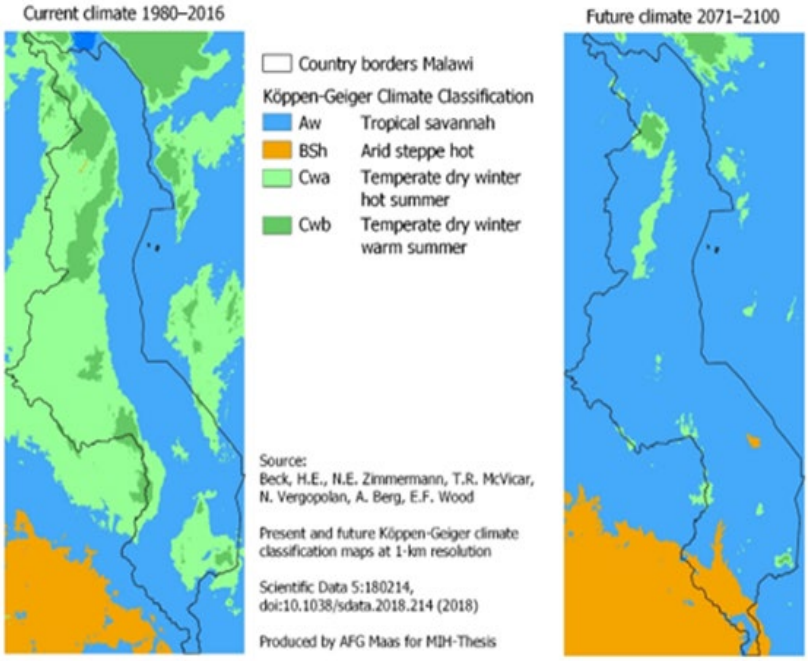


Figure 8: The Earth's Carbon Budget visualised by Dane McFarlane and Elizabeth Abramson (177)

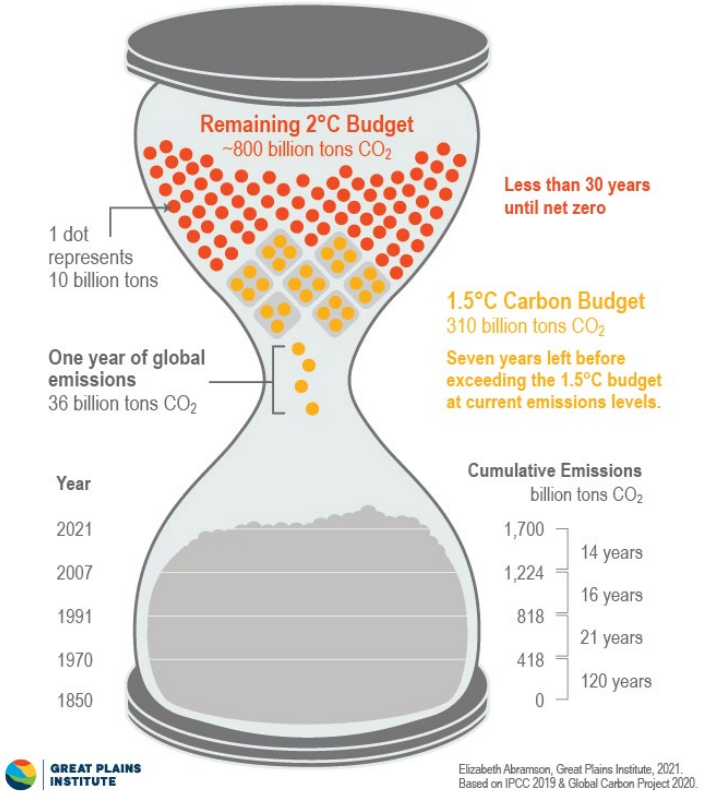
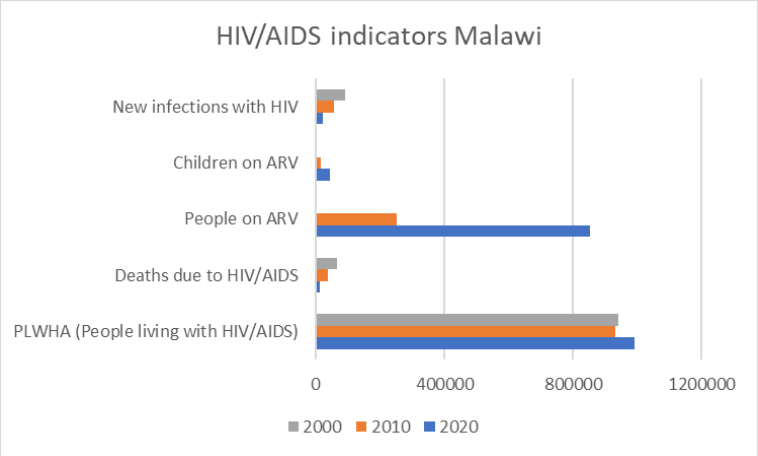


Figure 9: HIV/AIDS indicators Malawi



Source: WHO Global Health Observatory – Metadata – The Humanitarian Data Exchange (63)
For table with numerical data see annex 2, table 5

Figure 10: Trump ending the war on beautiful clean coal

Source: CNN, Dominick Reuter / AFP / Getty Images (101)

Figure 11: Climate change and child health: an expanded framework (12)

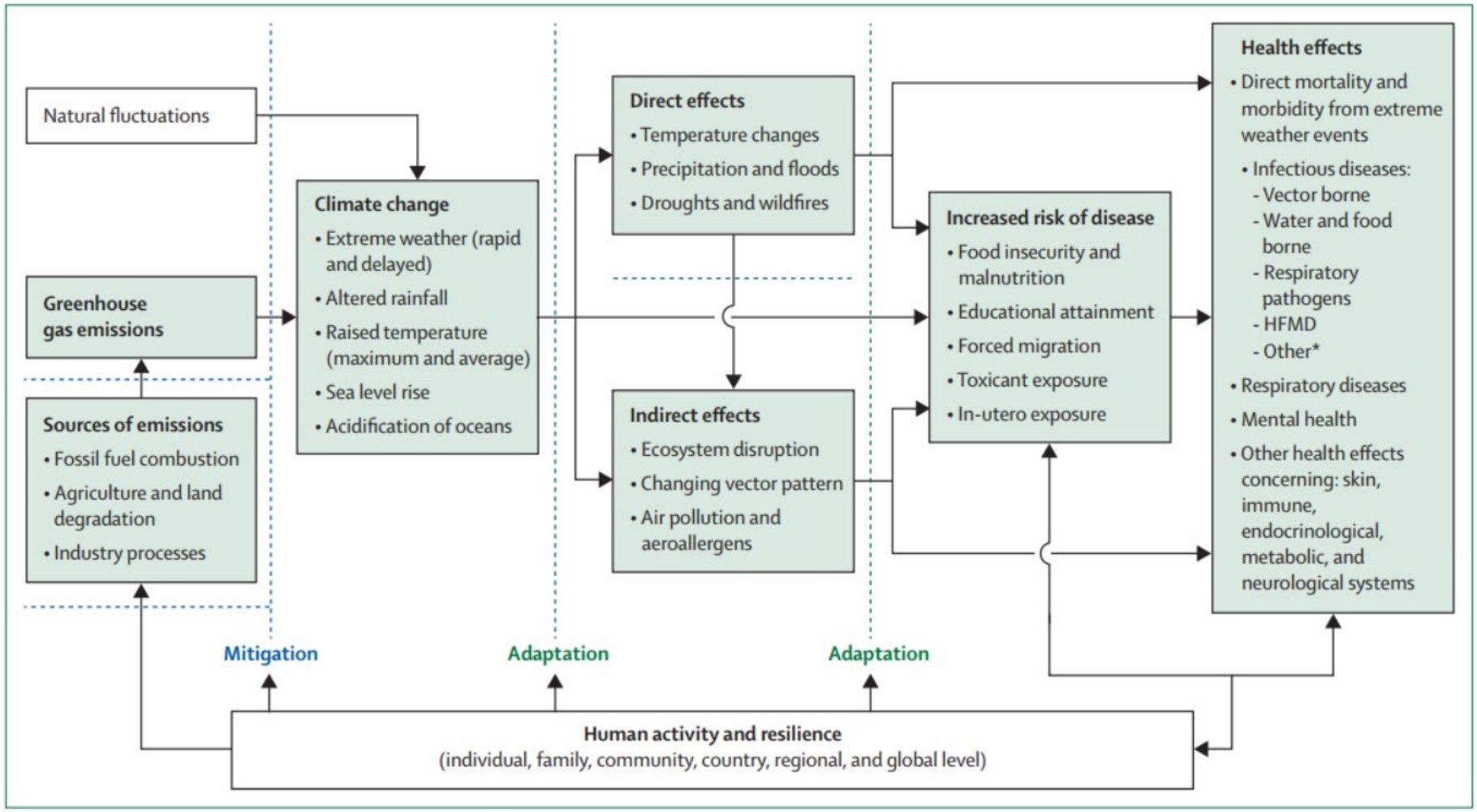


***Figure 3*: Climate change and child health: an expanded framework**

The dashed lines show where mitigation and adaptation can hinder the effects of climate change on child health and wellbeing. HFMD=Hand, foot, and mouth disease. *Other infectious diseases, from mumps to bacterial meningitis, varicella viruses, and parasitic diseases.

Figure 12: Mechanisms by which the harmful effects of ecosystem change can affect human health (Millennium Ecosystem Assessment) (3)

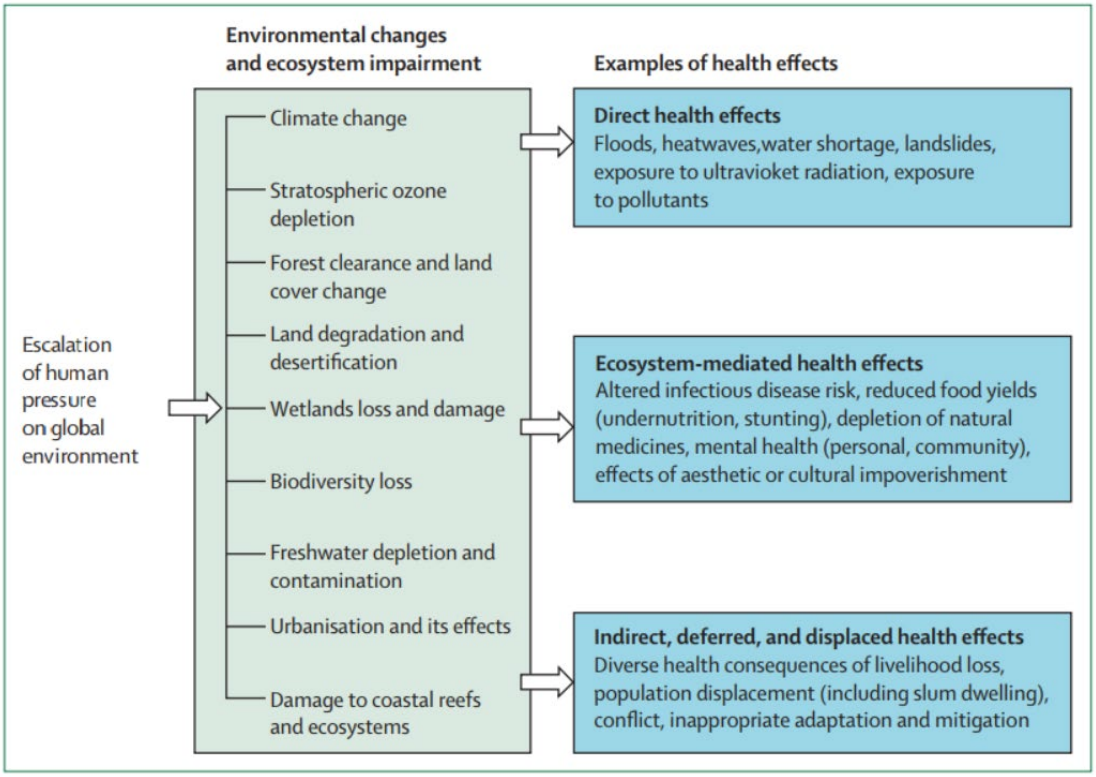


Figure 13: The pathways between climate change and human health (107)

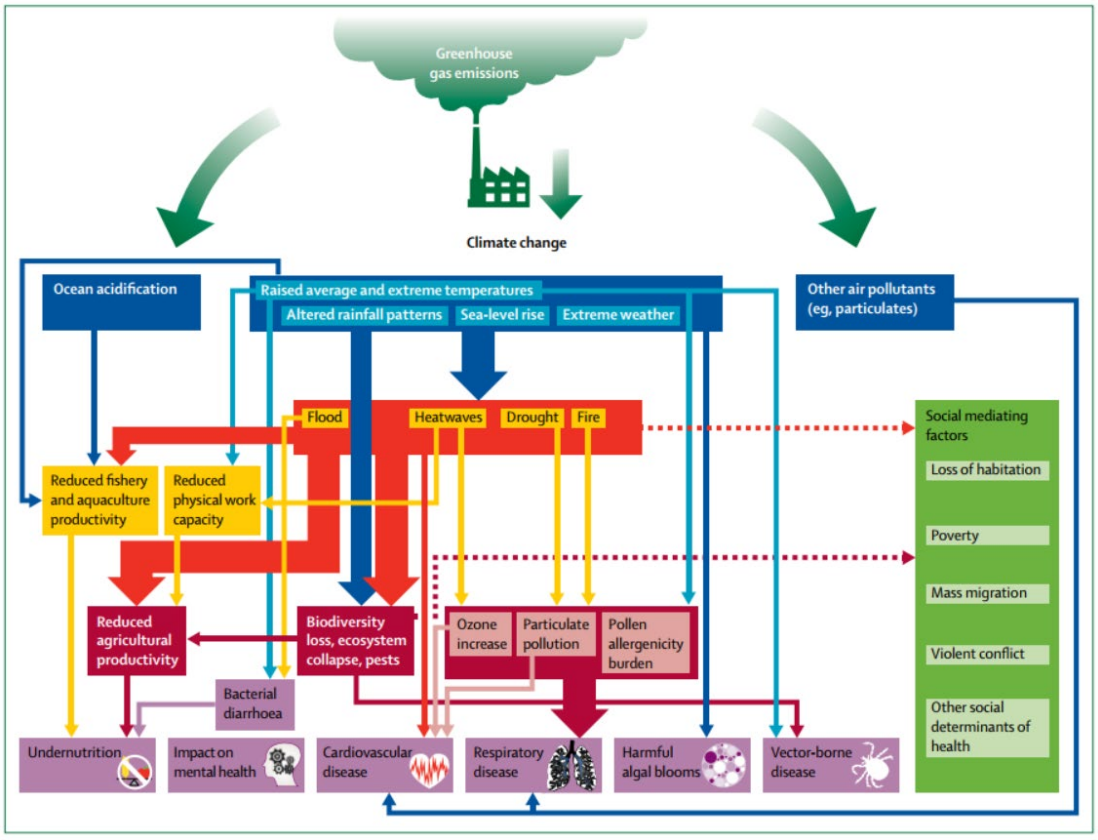


Figure 14: Sustainable livelihoods framework (108)

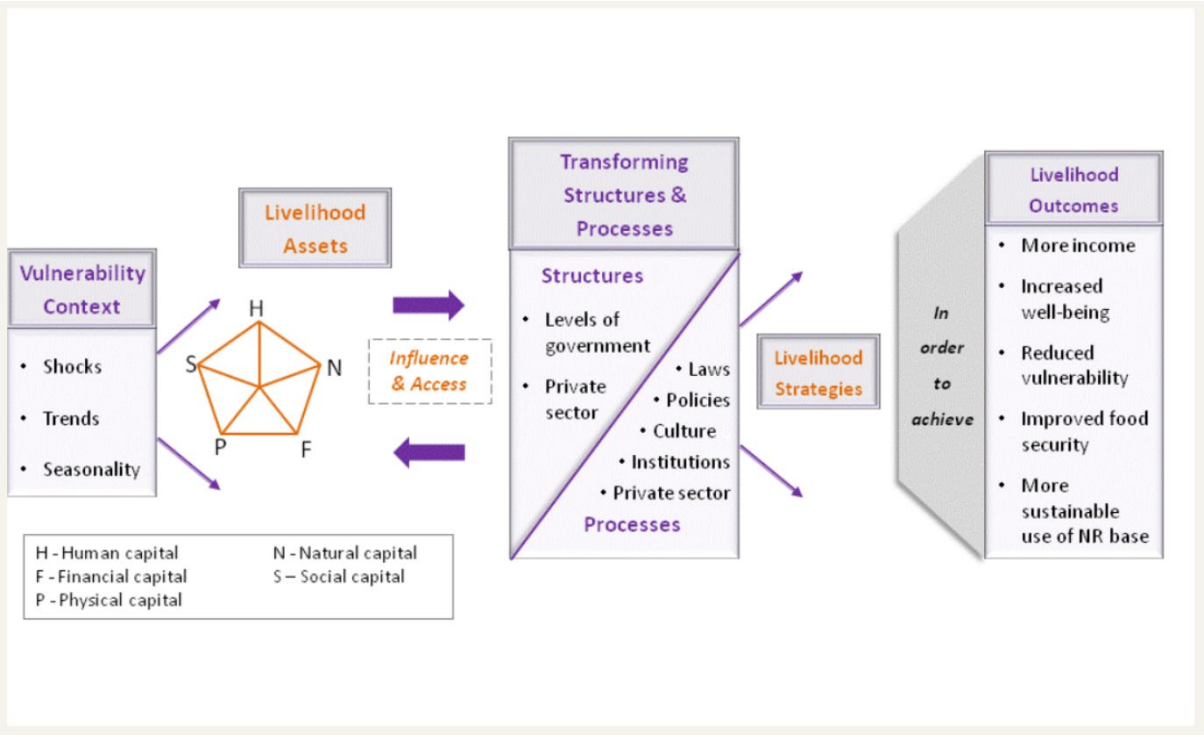


Figure 15: Climate change effects as distal (left) and proximal (right) determinants

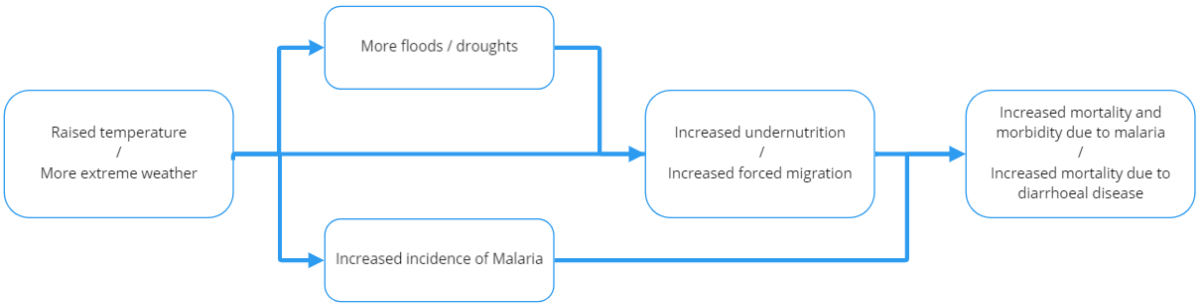
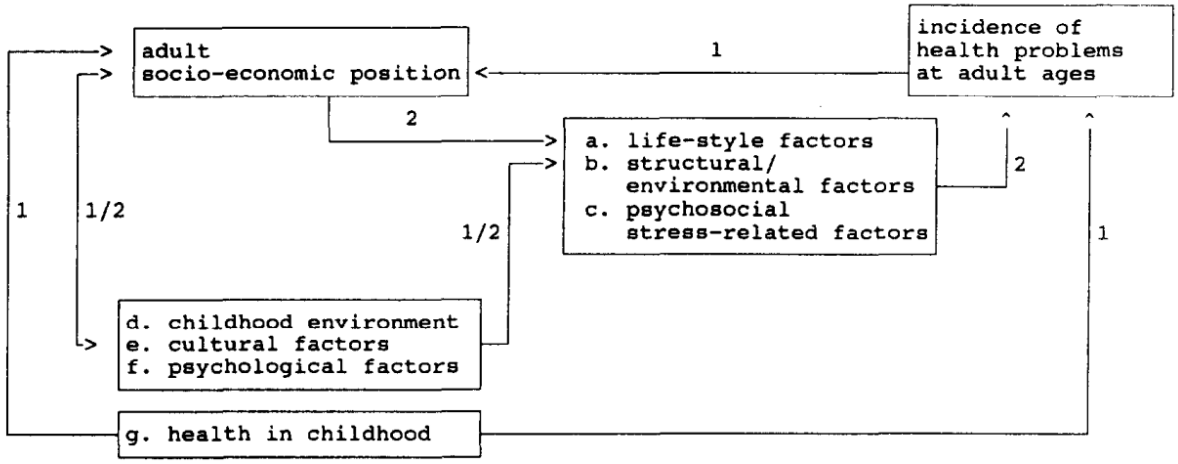


Figure 16: Graphical representation used in design of LS-SEHD / GLOBE study (111)



1 'selection' mechanism

2 'causation' mechanism

Fig. 1. A graphical representation of mechanisms and factors hypothesized to be involved in the explanation of socio-economic inequalities in the incidence of health problems at adult ages.

Figure 17: Main determinants of health model by Dahlgren and Whitehead (112)

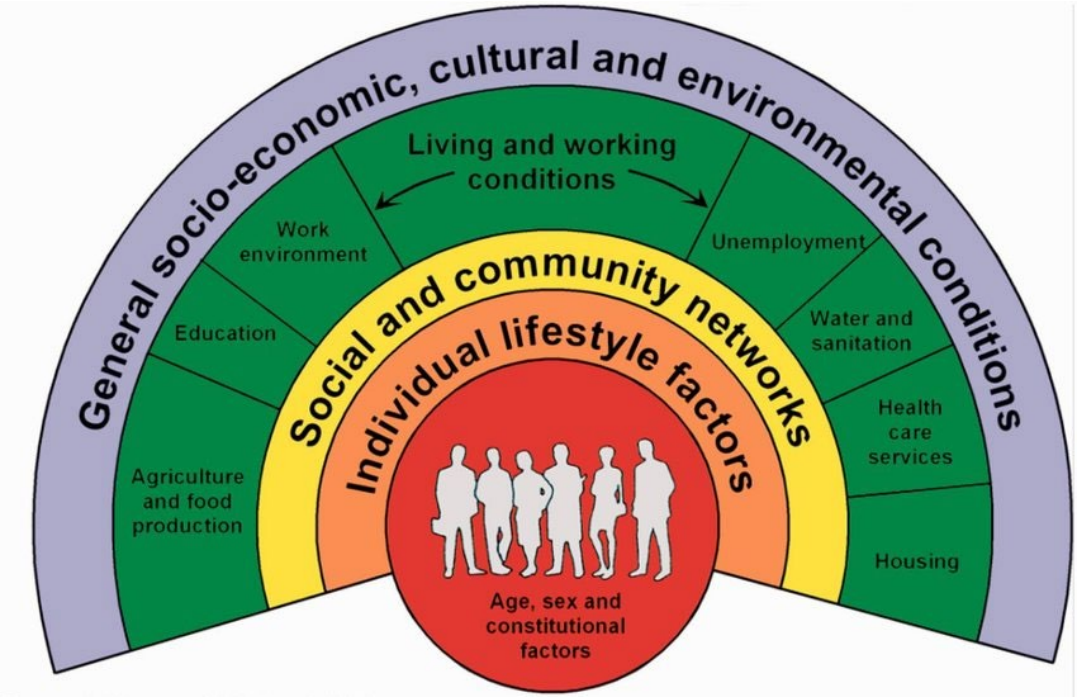


Figure 18: Conceptual framework for action on the SDH by the CSDH (113)

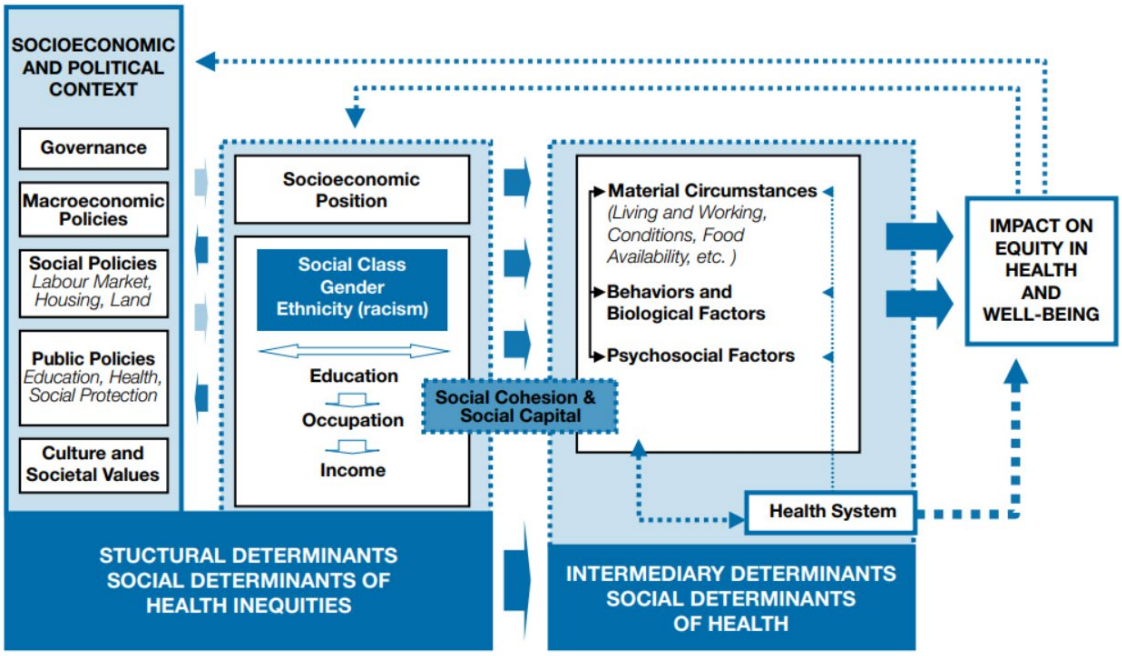
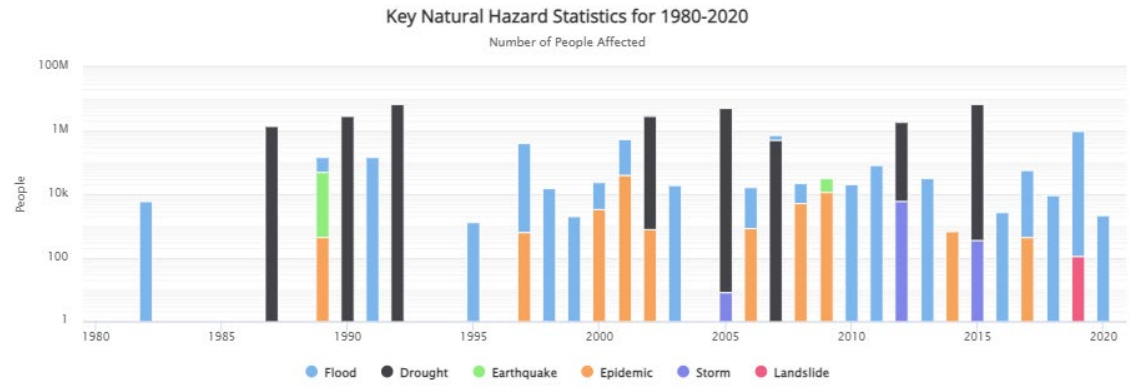
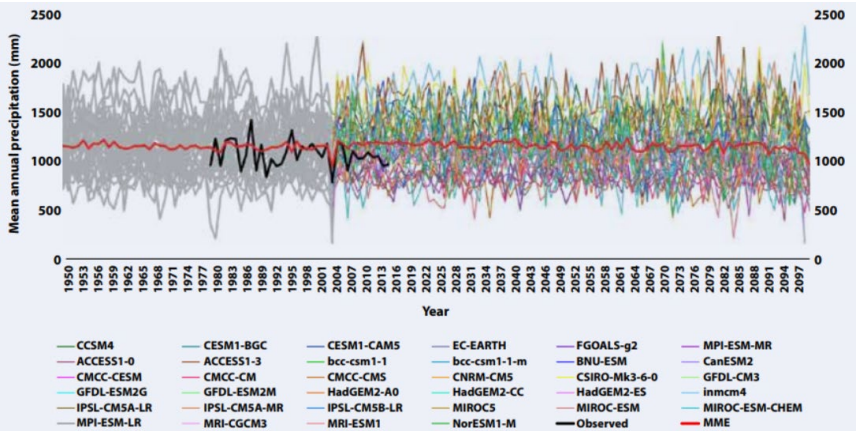


Figure 19: natural hazards in Malawi (World Bank)



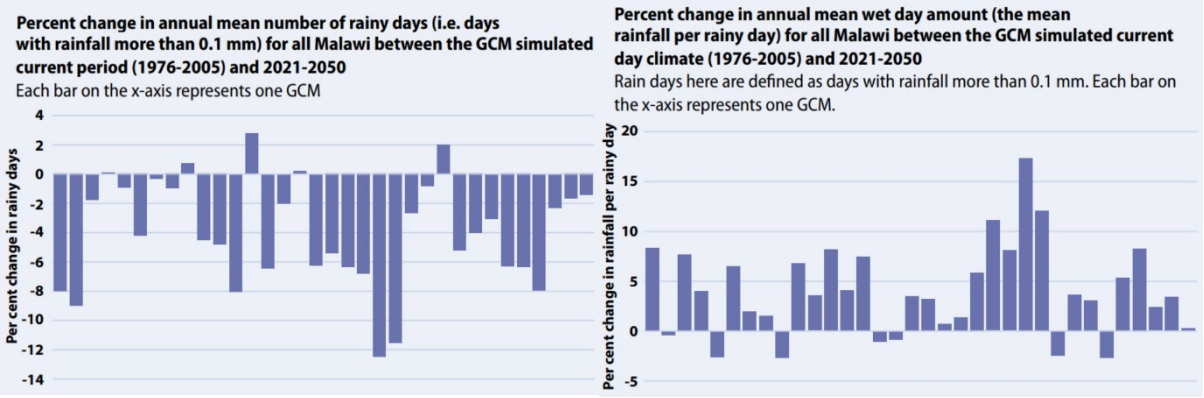
Source: World Bank, climate change knowledge portal (114)

Figure 20: Annual rainfall for Malawi in 34 CMIP5-models, ensemble mean in bold red



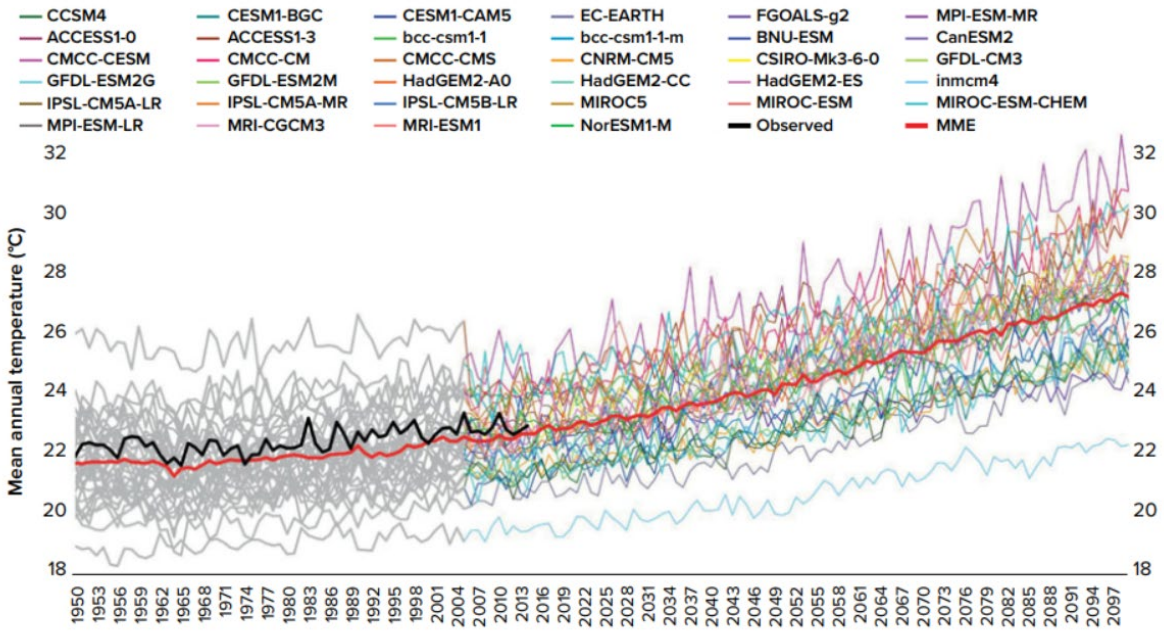
Source: Future Climate For Africa (FCFA) (126)

Figure 21: Percentage change in mean days with rainfall and rainfall per rainy day, Global Climate Models on the x-axis



Source: Future Climate For Africa (FCFA) (126)

Figure 22: Time series of mean annual temperature (C°) for 34 CMIP5 models



Source: UMFULA. 2017. *Malawi Country Climate Brief: Future Climate Change Projections for Malawi.*

Note: CMIP = Climate Model Intercomparison Project.

Source: Future Climate For Africa (FCFA) (129)

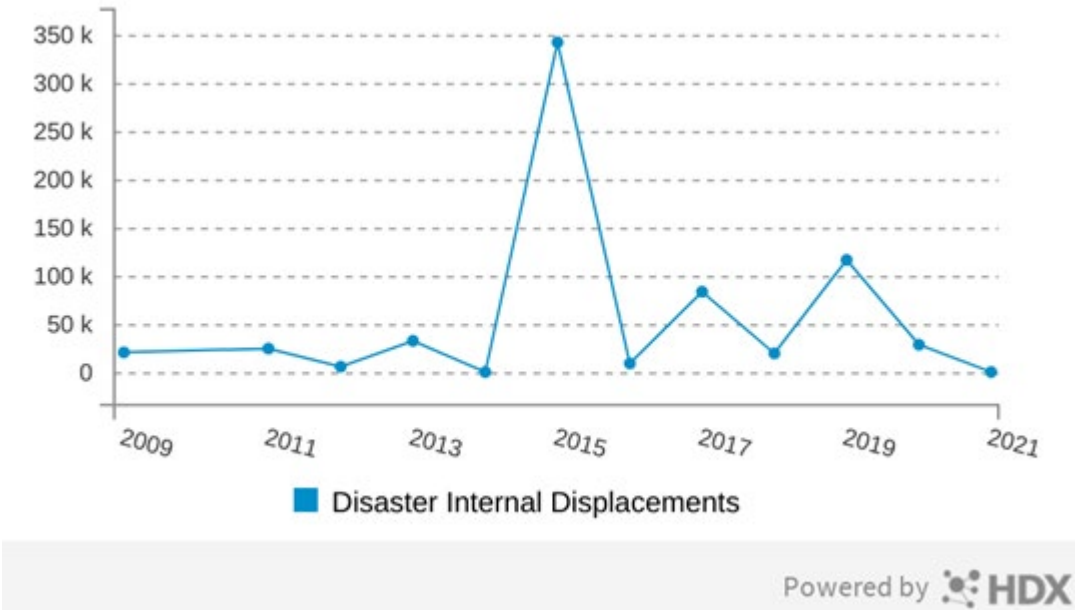
Figure 23: Flooded village in Lower Shire in 2015 after the highest rainfall on record

Source: Malawi 2015 Floods Post Disaster Needs Assessment Report (124)

Figure 24: Destroyed crops during the floods in 2015

Source: Malawi 2015 Floods Post Disaster Needs Assessment (124)

Figure 25: Internal displacements after disasters in Malawi

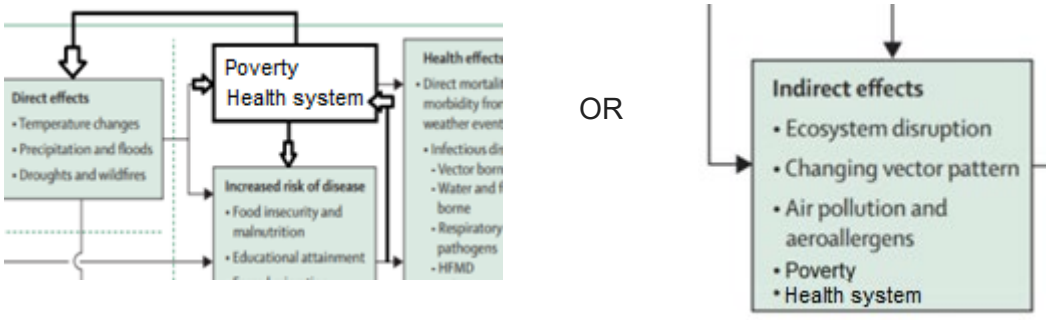


Source: Humanitarian Data Exchange (156)

Figure 26: The Sustainable Development Goals

Source: ***https://www.un.org/sustainabledevelopment/news/communications-material/***

Figure 27: possibilties for introducing poverty and the health system in the framework



Source: altered expanded framework of Helldén et al (12)

Annex 2: Tables

Table 1: Country information: The Republic of Malawi

Land area	118.484 km^2 (20% water)
Population	18.6 million
Capital city	Lilongwe
Main towns	Blantyre, Zomba, Mzuzu
Climate	Tropical (cooler in highlands)
Official language	English
Common language	Chichewa
Currency	Kwacha
President	Dr. Lazarus McCarthy Chakwera
Government Ministries	21

Source: https://www.malawi.gov.mw, accessed 25-05-2022 (54)

Table 2: UN Population Prospects 2019 Malawi

	Total population *in millions*	Under 5 years *in millions*	Under 15 years *in millions*
1950 (estimation)	3.0	0.6	1.3 (46% of total)
1990 (estimation)	9.4	1.7	4.2 (45% of total)
1992 (estimation)	9.7	1.8	4.4 (45% of total)
2015 (estimation)	16.7	2.8	7.6 (45% of total)
2030 (projection)	24.8	3.5	9.6 (39% of total)
2050 (projection)	38.1	4.3	12.3 (32% of total)
2100 (projection)	66.6	4.3 (peak 4.6 in 2072)	13.2 (peak 13.8 in 2077)

Source: World Population Prospects 2019 (56)

Table 3: Causes of child death in Malawi for children under 5 and 5-19 year

	Under 5		5-19 year	
	1990	2019	1990	2019
Cause	n (%)	n (%)	n (%)	n (%)
All causes	94296 (100)	31820 (100)	7632 (100)	7890 (100)
Asthma	186 (<0.5)	60 (<0.5)	43 (0.6)	48 (0.6)
Congenital birth defects	4238 (4.5)	2355 (7.4)	101 (1.3)	144 (1.8)
Dengue	11 (<0.5)	6 (<0.5)	3 (<0.5)	5 (<0.5)
Diarrheal diseases	17404 (18.5)	2679 (8.4)	730 (9.6)	823 (10.4)
Drowning	430 (0.5)	140 (<0.5)	105 (1.4)	104 (1.3)
Environmental heat and cold exposure	23 (<0.5)	9 (<0.5)	12 (<0.5)	14 (<0.5)
Exposure to forces of nature	0	8 (<0.5)	0	20 (<0.5)
Fire, heat and hot substances	240 (<0.5)	94 (<0.5)	35 (<0.5)	39 (<0.5)
HIV/AIDS	3020 (3.2)	808 (2.5)	552 (7.2)	1689 (21.5)
Lower respiratory infections	11038 (11.7)	4104 (12.9)	510 (6.7)	439 (5.6)
Malaria	17136 (18.2)	3990 (12.6)	1104 (14.5)	759 (9.6)
Measles	6277 (6.7)	183 (0.6)	715 (9.4)	27 (<0.5)
Meningitis	3593 (3.8)	892 (2.8)	552 (7.2)	434 (5.5)
Neonatal disorders	14292 (15.2)	10220 (32.1)		
Neoplasms	1359 (1.4)	644 (2.0)	269 (3.5)	501 (6.3)
Non-communicable diseases	7473 (7.9)	3799 (11.9)	1034 (13.6)	1587 (20.1)
Poisonings	204 (<0.5)	67 (<0.5)	33 (<0.5)	35 (<0.5)
Protein-energy malnutrition	4732 (5.0)	1066 (3.4)	227 (3.0)	123 (1.6)
Road injuries	455 (0.5)	154 (0.5)	370 (4.9)	458 (5.8)
Self harm			89 (1.2)	137 (1.7)
Tetanus	365 (<0.5)	137 (<0.5)	34 (<0.5)	36 (<0.5)
Tuberculosis	1789 (1.9)	387 (1.2)	444 (5.8)	324 (4.1)
Whooping cough	1077 (1.1)	602 (1.9)	52 (0.7)	38 (<0.5)

*in red are the top 5 causes

Source: IMHE, Global Burden of Disease (67)

Table 4: Health indicators: The Republic of Malawi

Neonatal mortality rate	2020	19.1 / 1000 live births
Infant mortality rate	2020	29.0 / 1000 live births
Neonatal tetanus protection[1]	2020	87%
Under 5 mortality rate	2020	38.6 / 1000 live births
Life expectancy at birth	2019	65.6 years
Yearly deaths due to malaria (all)	2020	7165
Estimated malaria mortality rate	2020	37.5 / 100.000 population
Intermittent preventive therapy for pregnant women (IPTp) for malaria[1]	2020	48%
Stunting prevalence under 5 years	2020	37%
Wasting prevalence under 5 years	2019	0.6% (<-2SD)
Maternal mortality rate	2017	349 / 100.000 live births
Births in past 12 months (census)[2]	2018	576.606
Skilled birth attendance[1]	2020	96%
Institutional delivery[1]	2020	97%
Births by caesarean section	2010-2016	6.1 %
Deaths in past 12 months (census)[2]	2018	110.776

Source: WHO Global Health Observatory – Metadata – The Humanitarian Data Exchange (52)
[1] Multiple Indicator Cluster Survey (MICS) 2019-2020 (178)
[2] Census data 2018 (53)

Table 5: HIV/AIDS indicators Malawi

Year	PLWHA (People living with HIV/AIDS)	Deaths due to HIV/AIDS	People on ARV	Children on ARV	New infections with HIV	Prevalence of HIV among adults aged 15 to 49 (%)
2020	990.000	12.000	853.032	45.689	21.000	8,1
2010	930.000	39.000	250.953	15.733	57.000	10,7
2000	940.000	68.000	0	0	92.000	14,9

Source: WHO Global Health Observatory – Metadata – The Humanitarian Data Exchange (63)

Table 6: Economic indicators: The Republic of Malawi

GDP (current US$)	2020	12.18 billion USD
GDP per capita (current US$)	2020	636.3 USD
GDP per capita (PPP)	2020	1591.5 USD
Public sector dept (in percent of GDP)	2019	59.5%
Working age population (15-64y)*	2018	9.188.275 (52.3% of population)
Employed persons*	2018	5.389.463
Unemployed persons*	2018	1.224.602

Source: The World Bank - Data (179,180)
**Census data 2018* (53)

Table 7: Search strategy for analytical framework

OR	Framework (All Fields)	AND	“child health” (MeSH term)	AND	“Climate change” (MeSH term)
	Framework s (All Fields)		“child” (All Fields) AND “health” (All Fields)		“climate” (All Fields) AND “change” (All Fields)
	Frameworks (All Fields)		“child health” (All Fields)		“Climate change” (All Fields)

Table 8: Search strategy for potential adjustments or additions to the framework

	Limitations: published from 01-06-2019 until 01-01-2022 With and without: “framework”				
OR	“child health” (MeSH term)	AND	“Climate change” (MeSH term)	AND	“Malawi” (MeSH term)
	“child” (All Fields) AND “health” (All Fields)		“climate” (All Fields) AND “change” (All Fields)		“Malawi” (All fields)
	“child health” (All Fields)		“Climate change” (All Fields)		“Malawi s” (All fields)

Table 9: Key words used in search strategy

Chapter 1

Child health related search terms		**Climate change related search terms**		**Analytical framework related search terms**		**Geography related search terms**
Child Health	AND / OR	Climate change	AND / OR	Extreme weather	AND	1st "Malawi"
Child		Climate		altered rainfall		Sub-Sahara Africa
Children				raised temperature		SADC
				sea level rise		Southern Africa
				acidification of oceans		Eastern Africa
						Tanzania
						Zambia
						Mozambique

Chapter 2

Child health related search terms		**Climate change related search terms**		**Analytical framework related search terms**		**Geography related search terms**
Direct effects						
Child Health	AND / OR	Climate change	AND / OR	Temperature change	AND	1st "Malawi"
Child		Climate		Precipitation and floods		Sub-Sahara Africa
Children				Droughts and wildfires		SADC
						Southern Africa
						Eastern Africa
						Tanzania
						Zambia
						Mozambique
Indirect effects						
Child Health	AND / OR	Climate change	AND / OR	Ecosystem disruption		
Child		Climate		Changing vector pattern		
Children				Aeroallergens		
				Air pollution		

Chapter 3

Child health related search terms	AND / OR	**Climate change related search terms**	AND / OR	**Analytical framework related search terms**	AND	**Geography related search terms**
Child Health		Climate change		food insecurity and malnutrition		1st "Malawi"
Child		Climate		educational attainment		Lake malawi
Children				forced migration		Sub-Sahara Africa
				toxicant exposure		SADC
				in-utero exposure		Southern Africa
				Food security		Eastern Africa
				School		Tanzania
				Undernutrition		Zambia
				poisoning		Mozambique

Chapter 4

Child health related search terms	AND / OR	**Climate change related search terms**	AND / OR	**Analytical framework related search terms**	AND	**Geography related search terms**
Child Health		Climate change		Direct mortality and morbidity from extreme weather events		1st "Malawi"
Child		Climate		Infectious diseases		Sub-Sahara Africa
Children				Respiratory diseases		SADC
				Mental health		Southern Africa
				Other health effects		Eastern Africa
				Pneumonia		Tanzania
						Zambia
						Mozambique

Table 10: Climate Change Risk Assessment (CCRA) estimations for Eastern Sub-Saharan Africa (SSA-E)*

		Stunting, moderate	Stunting, severe	Undernutrition	Malaria	Dengue	Diarrhoeal disease	Heat
SSA-E	2030	500.000	1.800.000	27.999	143	6	10.997	1.212
	2050	1.400.000	1.800.000	26.480	22.194	5	6.951	4.543
World	2030	3.600.000	3.900.000	95.176	60.091	258	48.114	37.588
	2050	6.200.000	3.900.000	84.697	32.695	282	32.955	94.621

Source: Climate Change Risk Assessment (CCRA) by WHO in 2014 (34)

* CCRA countries in Eastern Sub-Saharan Africa (SSA-E): Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, Sudan, Uganda, United Republic of Tanzania, Zambia (34)

Table 11: Databases searched

Pubmed : https://pubmed.ncbi.nlm.nih.gov/
Web of Science : https://www.webofscience.com
Cochrane Library : https://www.cochranelibrary.com
WHO – Institutional Repository for Information Sharing (IRIS) : https://apps.who.int/iris/
The World Bank – Open Knowledge Repository https://openknowledge.worldbank.org/discover & https://climateknowledgeportal.worldbank.org/country/malawi
Google Scholar https://scholar.google.com/
WHO regional website for Africa https://www.afro.who.int/search
Scopus : https://www.scopus.com
LibSearch of the Free University of Amsterdam (a.o. CINAHL, ERIC, WorldCat, ScienceDirect, PsychINFO, Pubmed Central, BioMed Central). https://vu.nl/en/about-vu/divisions/university-library
UN organisations (UNICEF, Reliefweb.int, UNDP, UNEP) https://www.unicef.org/reports & https://reliefweb.int/country/mwi & https://www.undp.org/ & https://www.unep.org/
Red Cross Red Crescent Climate Centre : https://www.climatecentre.org/search-results/
Save the Children : https://resourcecentre.savethechildren.net/

Table 12: Websites searched of government of Malawi

Websites searched for publications on climate change, policies and child health:
https://www.malawi.gov.mw/
https://www.health.gov.mw/
https://www.finance.gov.mw/index.php/departments/national-statistical-office
https://www.metmalawi.gov.mw/
https://www.ead.gov.mw/
https://www.malawi.gov.mw/opc/index.php/departments/dodma

Annex 3: Malawi's Health System

Health conditions in Malawi are in general poor (72). Malaria and cholera are endemic and malnutrition is prevalent (ibid).

1) Service delivery: In total there were 9498 reported health facilities in 2016 of which 5090 were outreach based, 3542 village clinics and 85 hospitals, 85% of population lives within 8 km of a health facility (161,181). The largest non-public sector provider of health service is the Christian Health Association of Malawi (CHAM) providing 29% of all health services in Malawi (161). Children born further from health facilities were at higher risk of dying before the age of 5 years, however reduction of this distance by the construction of new health facilities did not change the risk of dying before the age of 5 suggesting other factors are also important (182).

2) Health workforce: the total health workforce (2012-2020) consists of a.o. 0.5 medical doctors, 7.1 nurses and midwifery personnel, and below 0.1 dentists and pharmacists per 10,000 people, totalling 8.04 health workers per 10,000 population (183,184). In 2013 there was a shortage of 4.2 million health workers in the African region, this is projected to increase in 2030 to a shortage of 6.1 million in a needs-based estimation which requires 44.5 health workers (physicians, nurses / midwives, other cadres) per 10,000 population (185).

3) Health information systems: Malawi has a Health Management Information System (HMIS) unit under the Central Monitoring and Evaluation Division (CMED), which a.o. gathers monthly information from District Health Offices (DHO) and central hospitals (181). Of the children under 5 years 22% had a birth certificate, 73% of mothers / caregivers did not know how to register their child's birth (186). National surveillance is based on the Integrated Disease Surveillance and Response (IDSR) strategy, measles control is overall succesfull despite a large outbreak in 2010 (187). An overview of health indicators is provided in table 4 (next page).

4) Medical products, vaccines and technologies: The Essential Health Care Package (EHP) is used to guide free service provision, by using a cost-effectiveness analysis (CEA) it is possible to make prioritizations of population based interventions under a constrained budget (161). Resources available for drugs, medical supplies and commodities totalled 142 million USD for the fiscal year 2015-2016 (161). With the revised EHP costs are 5.97 USD / DALY averted (161). Acute bacterial meningitis (ABM) in children under 5 decreased rapidly after introduction vaccination, the incidence of ABM in children from 3 months to < 5 years dropped from 154.4/100000 in 2002 to 20/100000 in 2012 (157). Pneumococcal conjugate vaccine (PCV13) was introduced nationally in 2011 (66).

5) Health system financing: Government expenditure on health in Malawi was less than 10% of total government expenditure in 2010 (181). Health insurance is very uncommon, even in rich or urban areas only 4% of people aged 15-49 years are covered by health insurance (186). Health services are provided by public, private not for profit (PFNP) and private for profit (PFP) sectors, health services in the public sector are free-of-charge at the point of use, most health services provided by the PFP and PFNP sector charge user fees (161).

6) Leadership and governance: Malawi does not have the institutional capacity to deal with current or future climate risks (55). Climate change risks overwhelming and collapsing the fragile health and sanitation systems of Malawi (72). In the National Resilience Strategy it was stated: floods and droughts are inevitable in the region but should not result in disasters that lead to life and livelihoods (60). In 2020 the document Malawi's Vision 2063 (100th anniversary of self-governance) was published by the

National Planning Commission in which ambitious plans are envisioned with a.o. climate smart and resilient agriculture and also a focus on early childhood development (188).

Table 4: Health indicators: The Republic of Malawi

Neonatal mortality rate	2020	19.1 / 1000 live births
Infant mortality rate	2020	29.0 / 1000 live births
Neonatal tetanus protection[1]	2020	87%
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Wasting prevalence under 5 years	2019	0.6% (<-2SD)
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Skilled birth attendance[1]	2020	96%
Institutional delivery[1]	2020	97%
Births by caesarean section	2010-2016	6.1 %
Deaths in past 12 months (census)[2]	2018	110.776

Source: WHO Global Health Observatory – Metadata – The Humanitarian Data Exchange (52)
[1] Multiple Indicator Cluster Survey (MICS) 2019-2020 (178)
[2] Census data 2018 (53)

The HIV/AIDS pandemic has had a devastating effect on Malawi, life expectancy decreased from 48 years in 1987 to just below 40 in 2005 (115). Malawi still is in the top 10 countries with the highest HIV prevalence rates in the world (14.9% in 2000 and 8.1% in 2020) which has weakened institutional capacity because of a.o. staff attrition (morbidity, deaths etc.), disease related absenteeism, increased workload, low morale, loss of institutional memory and persisting vacancies (115,189). General HIV/AIDS indicators are presented in figure 9, annex 1. Prevention of mother to child transmission (PMTCT) policies have been successful so far: in 2010 only 13,967 out of 52,000 (26.9%) pregnant women received antiretroviral (ARV) therapy out of those who needed it, compared to 41,391 out of 40,000 (103.5%) in 2020 (63). The unmet need for modern contraceptive use is 72% for unmarried girls and 21% for married girls age 15-19 (186).

Annex 4: Malawi's Economic Situation

Malawi is the sixth poorest country in the world and its pace in poverty reduction has been very slow (48). The proportion of population that was poor in 2019 was 50.8% (174). Children who grow up impoverished often lack the food, sanitation, shelter, health care and education they need to thrive and survive (190). Economic growth has fallen due to the COVID-19 pandemic but is expected to recover during 2022-2025 with average growth of 6.4% (68). Government financing has benefited in the past of the dept relief for Heavily Indebted Poor Countries (HIPC) by the International Monetary Fund (IMF) in 2006 (191). The public sector dept dropped from 158.6 % in 2005 to around 37.4% of GDP in 2006 (ibid). For general information on the economy, see table 6.

The majority of the population depends on rainfed agriculture (48), 85% of the households are involved in subsistence farming (69), 91% of the households are engaged in crop production relying only on rain and 8.3% could rely on both irrigation and rain (153). The agriculture sector dominates the economy, accounting for almost 30% of GDP, around 75% of total exports and 64% of the labour force (48). Malawi depends on a weak and undiversified export base, mainly consisting of primary commodities such as tobacco, tea and sugar (48). Extreme weather has had severe consequence on the economy in the past, the costs of floods and droughts since 2012 are over 1 billion USD (55) and have resulted in the third highest count (out of 16 countries) of food insecure people of the Southern African Development Community (SADC) member states, with a maximum of 6.7 million in 2016 (135). National food security is closely linked to maize harvest and access to maize (128). Total production in 2018-2019 of tobacco by far (>40 times) exceeds maize production (138.4 million metric tons MMT vs 3.4 MMT) (192). Other important crops for Malawi are cassava, groundnuts, peas, potatoes, pulsus and sorghum (128). Total production of tobacco is for 95% accounted for by smallholder farmers (193). Although efforts are made in shifting from tobacco, this still remains difficult: "For a Malawian farmer to compete with an American or European farmer who are heavily subsidized, it is very difficult", most middle- and high income countries spend more on agricultural subsidies than the total GDP of Malawi (193). Around 5.6 million children are laborers in Malawi, of those 2 million are working in agriculture and around 100.000 children are working on tobacco farms (194), in the Multiple Indicator Cluster Survey (MICS) of 2019-2020 an estimated 14% of children aged 5-17 years were involved in child labour (186).

Of all households 58% owned a mobile phone, 31% owned a radio, 11% of households had access to electricity, 11% owned a television set, 4% owned a computer and 1% had a fixed telephone line, 12% of households had access to internet (186). Amongst the poorest people, aged 15-49 years, only 8% of women and 19% of men owned a mobile phone in contrast to the richest adults with 69% of women and 75% of men (186,195)

Table 6: Economic indicators: The Republic of Malawi

GDP (current US$)	2020	12.18 billion USD
GDP per capita (current US$)	2020	636.3 USD
GDP per capita (PPP)	2020	1591.5 USD
Public sector dept (in percent of GDP)	2019	59.5%
Working age population (15-64y)*	2018	9.188.275 (52.3% of population)
Employed persons*	2018	5.389.463
Unemployed persons*	2018	1.224.602

Source: The World Bank - Data (179,180)
**Census data 2018* (53)

Annex 5: Supplementary materials

Chapter 1:

Extreme weather:

When AR4 was published by the IPCC in 2007 it was stated that current climate is already impacted due to climate change in the form of long-term and widespread changes in wind patterns and aspects of extreme weather including droughs, heavy precipitation, heat waves and the intensity of tropical cyclones (196,197). Although Malawi is at risk for earthquakes due to it's location in the East African Rift System (198), it is unclear whether climate change will affect this risk and thus so far unknown whether it will impact direct risks or risks of disease by for example affecting food security or inducing forced migration.

Sea level rise:

Sea levels have risen already by 0.16m from 1908 until 2010 and in recent decades the rate of sea level rise has increased (199). It will continue to rise due to thermal expansion, melting of glaciers and ice sheets and land water storage changes, projections of global mean sea level rise vary between 0.43m and 0.84m for respectively RCP2.6 and RCP 8.5 scenarios in 2100 compared to 1986-2005 (199). The lowest point of Malawi is 37 meters above sea level in the south of the country where the Shire rivel will eventually drain into the Zambezi river (200).

Ocean acidification

The oceans absorb nearly one-third of CO2 that is emitted in the atmosphere, due to the increased anthropogenic emissions this results in an acidification of the oceans (201). The acidification of oceans will have complex consequences, the pH of oceans could decrease to 7.7 in 2100, coming from 8.1 in 1950 (5,201). It affects coral reefs, impairs the development of oysters and other shellfish and dissolves calcium containing microorganisms at the base of the food web (201). It is described that the acidification of oceans increases the accumulation of pollutants in seafood and interacts with metals that can be toxic (201,202). If this has the same consequences for inland lakes this could be potentially relevant for child health in Malawi, since proteins from seafood are a considerable part of the diet.

Chapter 2:

Temperature change

Child mortality related to heat exposure is predicted to cause over 100.000 deaths per year by 2050 globally (147). In Malawi extremes in temperature like hot and very hot days are also more likely to occur (55). In general, children and the elderly, those with underlying medical conditions, and the poor are most at risk of temperature-related mortality (121,147).

Very young children are especially vulnerable to heat-related deaths, including dehydration, as they cannot regulate their temperature and control their environment (36). Children experience a greater increase in core temperature for any given level of hypohydration, increasing their physiological strain and reducing tolerance for heat, hypohydration is therefore a major risk factor for heat-related illness (147). In general there are limited child-adult difference in thermoregulation during mild and moderate heat exposure, with increased risk of heat illness only at environmental extremes (ibid).

Limited studies have been done in low-income countries (166,203). No studies were found on the direct effect of heat-waves or increased temperature on child morbidity or mortality in Malawi, on a household level heat-waves were not associated with mortality and cold snaps were associated with lower mortality in Malawi (121). Delayed onset of rains for extended periods of drought in the Lake Malawi basin potentially results in total loss or reduction of

hydropower generation capacity due to cessation of flow of the Shire River which could impact the health system (17).

Chapter 3

Educational attainment

Education attainment is influenced by climate change in several ways, firstly by direct impact of extreme weather, secondly impacts of increased temperatures, thirdly through increased poverty. If households are unable to pay school fees, and participate in income generating activities during school age (child labour), educational outcomes will be negatively affected (155). This can have significant consequences later in life, positive, for example mother's education appears to have a positive impact on reducing malnutrition (123), but also negative, through decreased human capital investment when schools are destroyed, decreasing the expected income in the future (204).

The direct impact of extreme weather on education attainment has been significant. During the floods of 2015 508 classrooms were damaged or destroyed and 222 schools acted as camps for internally displace people (124).

In 2019 after the tropical cyclone Idai most affected people were accomodated in temporary internally displaced people (IDP) camps, mostly located in classrooms and school facilities with limited access to safe water and sanitation facilities, girls were often required to travel long distances to collect water and firewood limiting the ability to attend classes (69). This resulted in significant disruptions to learning and teaching activities at the school (69). Also significant damages occurred to 154 schools, around 5000 desks and over 60.000 school books (ibid). During the tropical storm Ana in 2022 almost 500 schools were damaged (133).

The impact of higher temperature works in more indirect ways. In a large study of 10 million students in the United States heat clearly impact their learning ability, for every 1°F a hotter school year, that year's learning reduced by 1% (205), here comes the energy catch: aircondition was able to reduce this effect. In general higher ambient air temperature during schooling also lead to negative effects on the wellbeing of children, leading to absenteeism (12,206). Increasing ambient air temperatures could possibly decrease the learning ability of children. When schools are used as IDP camps for a prolonged time educational attainment will be impacted.

The drying of Lake Chilwa was associated with an increased number of early marriages in daugthers (72). Resulting amongst other issues in more drop outs from school (138).

Forced migration

Malawi has experienced numerous severe flooding events linked to the El Niño / La Niña phenomena which have caused displacements, injury and death (72). Through changes in the supply of natural resourses and disagreement over their allocation climate change and variability may increase the incidence of violent conflicts (121). So far this has not been a reported in Malawi. Basic drinking water services (indicator 1.4.1) was 74.2% (range 70-89% for wealth quintiles) (169).

In- and ex-utero exposure

The effects of in-utero exposure to air pollution and maternal nutritional status have been discussed in the corresponding subheadings. In Malawi in-utero exposure to drought was associated with delayed school entry among male children (155). Due to climate change the vulnerability to toxicants and pollution increases, mainly through increased ambient temperature, rainfall variabilty and exposure during/after floods (69,147,166), sources of toxicants and pollution coming for example from latrines, e-waste and industrial waste (17,69,207). In a study on inpatient child deaths within 12 months in a large government

hospital in Malawi 4 children died of poisoning by organophosphate, a fertiliser used in farming (66). It is possible cases like this will increase if not appropriate measures will be taken. Mercury-poisoning causes loss of cognitive function due to prenatal exposure in children by maternal consumption of mercury-contamined fish (201). But in Malawi the amount of mercury found in fish in lake Malawi was found to be low 2-200 ng/g wet weight of fish (208). Exposure to higher-than-average temperatures during the prenatal and early-life period is associated with fewer years of schooling in Southeast Asia (155).

Chapter 4

Direct mortality and morbidity from extreme weather events

Climate change will increase both the frequency and intensity of natural disasters such as extreme rainfall, floods, droughts, cyclones and extreme temperature events, these events directly affect household mortality when members drown in floods, die of heat stroke or become buried under debris.

Droughts have significantly increased mortality in Malawi in 2008-2009 (121). During the floods of 2015, 2019 and 2022 106, 90 and 50 people were killed respectively, no specific age disaggregation data was available (69,124,209). The tropical cyclone Idai injured 672 people, also no disaggregation of age was available (69).

The increase in number of “hot” days is predicted to lead to more heat-related deaths affecting predominantly the elderly but children and those with chronic illnesses are also projected to be at risk (72). Extreme heat / temperatures could be associated with an increase in miscarriages and stillbirths and can impact fetal development leading to adverse birth outcomes like low birth weight and preterm birth (12,155). No studies were found which were conducted in Malawi on this topic.

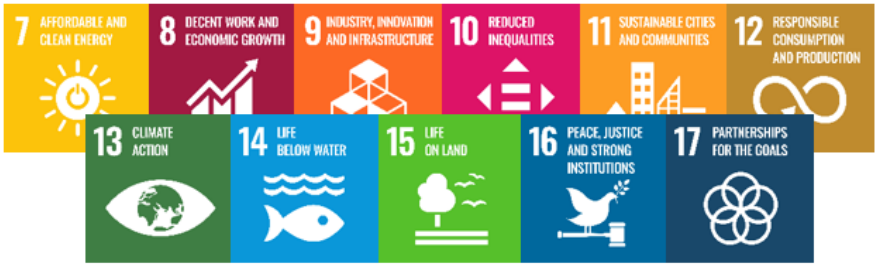
Damaged (health) infrastructure will impact mortality and morbidity through decreased access to care.

Infectious diseases

African countries reported 94% of the 229 million malaria cases recorded globally in 2019 (80). Cholera outbreaks in South Asia are linked with increasing water temperature and algal blooms (139). Average temperature change is associated with a change of geographical distribution of dengue, estimations put half of the world’s population at risk by the end of this century (12).

Mental health

Although the important reported impacts of climate change on mental health little has been published from Sub-Sahara Africa, in a recent systematic review (2021) only 2 studies were found from Sub-Sahara Africa in Namibia and Nigeria focussing on floodings where typical Post-Traumatic Stress Disorder (PTSD) symptoms were reported by children aged 8-18 years (210). No studies were found reporting on stress of Malawian children in relation to climate change. Stress may increase amongst farmers as a result of drier periods (72).



Some general comments on the rest of the SDG's:

Goal 7: Droughts could cause low flow rates in Shire River which reduced electricity generation (17) (target 7.1, 7.2).

Goal 11: Due to the repeated significant infrastructure damages target 11.1 (adequate, safe, affordable housing) and target 11.2 (providing safe and accessible roads and transportation) will continue to be a challence, vulnerability to children is mostly the loss of shelter, WASH facilities and access to healthcare. Target 11.5 aims at significantly reducing the number of people affected and killed due to disasters. The extreme weather events leading to the multiple disasters in the past decade have affected millions op people and in the case of cyclone Idai more then 450.000 children. Forced migration alse contributes to poverty (loss of physical capital), food insecurity (high dependency on subsistence farming), increased risk of disease due to loss of shelter and insufficient WASH facilities impacting the other SDG's.

With the National Resilience Strategy 2018-2030 and as signatory to the Sendai Framework for Disaster Risk Reducation Plan of Action important vulnerabilities in nutrition, Early Warning And Response Systems are being addressed. The National Resilience Strategy lacks integration with usefull health policies on for example malaria or specific WASH interventions like shock chlorination after flooding, it surprisingly also doesn't mention improving the build environment like housing of houses (62,170).

Goal 15: Using a Planetary Health / One Health approach could benefit food security by taking into account and preparing for disastrous plant and cattle diseases (target 15.8).

Goal 17: It is estimated that Malawi is facing potential annual average costs of 165 milion USD until 2050 without adaptation measures applied to planning, construction and maintenance road infrastructure, this could be used for advocacy in communication with other countries or the world bank in regards to target 17.3,17.4 (mobilising resourcs and assist developing countries in attaining long term-dept sustainability).

Annex 6: Consequences of extreme weather events

A short summary of relevant effects of some major extreme weather events:

1. In 2015 Malawi witnessed the worst floods in the last 50 years, a 1 in 500 year event, affecting over 1 million people (124).

Consequences on food security: around 90.000 hectares of cropland were destroyed and 195.000 livestock were lost, this led to an estimated 30% reduction in crop production (124). Admissions of children to Supplementary Feeding Programs (SFP), to treat Moderate Acute Malnutrition (MAM), increased by 58.3%, in the most affected districts admission rates increased by as much as 156-556% (ibid).

Damages to (WASH) infrastructure: 1220 km of roads and 185 bridges were damaged and downtime on average for the whole power system was 14 days (124). Irrigation infrastructure were damaged, water and electricity was in shortage, and over 500.000 houses were partially destroyed of which 356.643 completely destroyed (ibid). This led to an estimated 50 million USD in damages to road infrastructure and 136.4 million USD to the housing sector (124), total costs were 335 million (48,68,69,72,120). Almost 3000 boreholes and 6 water treatment plants were damaged / destroyed (124).

Displacement of people: around 230.000 people internally displaced

Decreased access to care: 23 health facilities were destroyed (124) Primary health care was limited in most to Internally Displaced People (IDP) camps (ibid).

2. The severe drought related to the El Nino event of 2016:

Consequences on food security: the drought resulted in a decline of 11.8% in national average annual level of consumption of the poorest 40% of the polulation compared to below 2% in neighbouring and SADC countries (48).

3. One of the worst tropical cyclones in the history of Malawi “Idai” in 2019 affecting almost 1 million people (69):

Consequences on food security: Due to the cumulative effect of the floods in 2015 and the drougth in 2016, still 3.3 million people were food insecure when the cyclone made landfall causing heavy rain and flooding (69). Around 91.638 hectares of crop land were destroyed and almost 50.000 livestock were lost (ibid). Total damages and losses amounted to 220.2 million USD (ibid).

Damages to (WASH) infrastructure: Roads, bridges, power supply, water supply equipment were amongst all things that were damaged, 288.371 houses were partially or completely destroyed (69). Over 250.000 latrines were collapsed, around 400 boreholes were damaged and over 300 were contaminated, the people who remained in the IDP-camps had limited access to safe water and sanitation facilities (69).

Displacement of people: the storm drove around 90.000 people to 174 temporary IDP camps, mostly located in classrooms and school facilities with limited access to safe water and sanitation facilities (69).

Decreased access to care: The damages significantly affected the country’s already limited maternity and paediatric facilities (72,134). 13 health facilities were damaged in Blantyre and Chikwawa by the floods with cases of refrigerators being washed away, medicine supplies lost, roofs blown off and water towers and toilets collaps (69). Also exposure to sexually transmitted infections (STI) increased due to the decreased access to condoms and possible unplanned pregnancies in the IDP camps were reported (ibid).

4. In the beginning of 2022 the floods related to tropical storm Ana in January and Gombe in March have caused flooding and significant damage affecting around 1.4 million people (80,133,209,211)

Consequences on food security: Around 100,000 hectares of cropland were destroyed, many households were displacement and livelihoods disrupted (133,209).

Damages to (WASH) infrastructure: Bridges, roads and 47 health facilities were damaged but also an important hydroelectric power station leading to interruptions of the power supply, it led to loss of drugs, damaged equipment / fridges / vaccines and others supplies (158). The damaged hydropower plant will also be very costly in its repair (133). Over 1,000 boreholes were damaged (133).

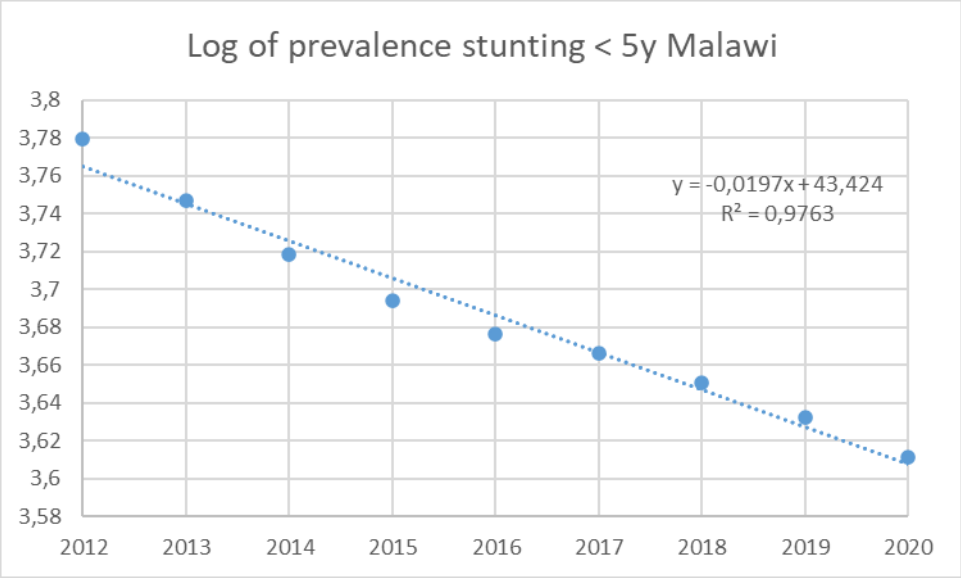
Displacement of people: over 240,000 people were internally displaced (133,209,211).

Decreased access to care: Access to potable water was impacted for 300,000 people after storm Ana (133). Over 20,000 pregnant women were in need of delivery kits and more than 90,000 under 5 children with SAM required urgent services in nutrition rehabilitation units which was not available (133,158).

Annex 7: Calculating the Average Annual Rate of Reduction (AARR)

The calculations were made based on the methodology of the technical note "How to calculate AARR of Underweight Prevalence" by UNICEF 2007 (64).

β = -0.0197 giving a AARR of 1.95% ; C_0 = 43.4



Source: Prevalence data of stunting <5y (63)

Reflection on SDG's

In the discussion paper by WHO/UNICEF published in 2019 (65) an AARR of 4% is considered feasible when setting the nutrition targets for the SDG's for 2030. It is stated that the top quintile of countries with prevalence rates > 20% at baseline have reached an AARR of ≥ 3.8 in the past years (with no relation between population and reduction) and that therefore, since global under five population is projected to grow with only 2.5%, it is considered feasible to have a 50% reduction in 2030 globally (65). Considering the under five population growth in Malawi to be 27.5% instead of 2.5% until 2030, the current AARR of 1.97% (global AARR of 2.3%) instead of 4%, the projected "difficulties due to climate change" and the current projected prevalence (based on current AARR) of 30.3% in 2030 instead of the target 50% reduction 21.9%, at this pace it will for sure not be feasible for Malawi to reach this target. Even with a herculian effort doubling the AARR to 4% from 2022 and onwards, still the prevalence will be 25.7% in 2030 instead of the target 21.9%.

Annex 8: Nutritional value Nsima / Corn meal / Corn starch

Due to the high prevalence of anemia and undernutrition in children, exploratory calculation were made to determine the nutritional value of the staple food for Malawi:

- Corn meal (whole grain kernel) ; ufa wa m'gaiwa
- Corn starch (no protein, starchy maize flour) ; ufa woyera

For the calculation corn based products were used although Nsima can also be made using cassave, sorghum (better in dry areas) or millet flour.

Conclusion for both the 5y old boy and girl:

1) Nutritional value Maize / Corn starch = Low fat, high carbohydrates, low protein, low fibre, no vitamin A, D, E, B1, B2, B6, B9, B12 or vit C, low calcium, Fe, P, Zn, Se, Ph, iodine
2) Nutritional value Maize / Corn meal = A bit higher fat, but insufficient, high carbohydrates, sufficient fibre, 2/3 of protein requirement, insufficient vit A, D, B2, B12, C, Calcium, Se, iodine, sufficient vit E, B1, Mg, Cu, Ph, half of daily requirements: B6, B9, Fe, Zn

Calculation were made for a 5 year old boy and a 5 year old girl.

- Body weights will be estimated using the WHO child growth standards: https://www.who.int/tools/child-growth-standards/standards/weight-for-age
- Calculations for nutritional value Nsima / Corn meal/starch were done using: https://www.kostholdsplanleggeren.no/comparefoods/?profileId=124&slot0Id=05.013&slot0Amount=364&slot0Unit=g&slot1Id=05.015&slot1Amount=355.0&slot1Unit=g
- Protein requirement was determined to be 0.9g/kg/d = 16.2 based on reference literature for 5 year old children (212)

Calculations for 5 year old boy

- Taking the 0 z-score on a weight for age chart from WHO, we will use 18 kg as calculating weight

Nutritional requirements:

- Henry's basal metabolic rate equation: (23.3 x (weight=18)) + 514 = 933kcal
- Physical Activity Level (PAL) 5y old boy 1.54 (213)
- 933*1.54 = 1436.8
- 90% = 1293.1 kcal

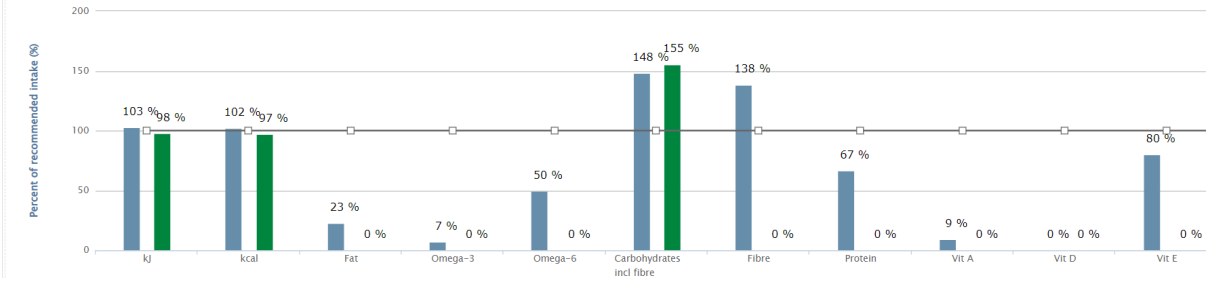
Amount of corn starch needed for adequate calorie intake: 355 kcal / 100gr = 364.3 gr / day for 90% of requirements
Amount of corn starch needed for adequate calorie intake: 364 kcal / 100gr = 355.2 gr / day for 90% of requirements

CHOSEN PROFILE

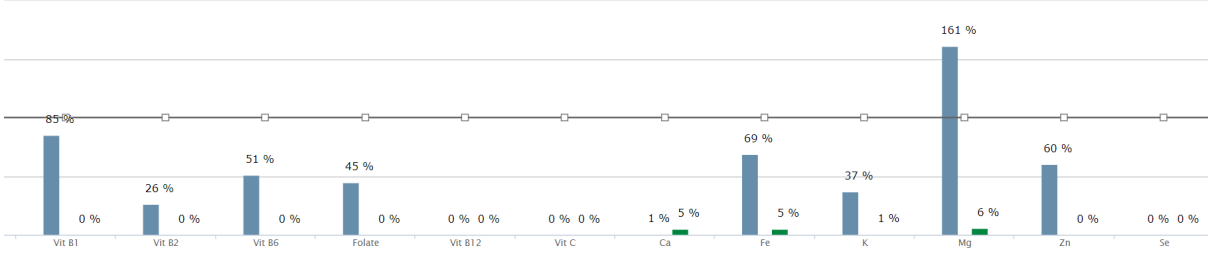
Boy | **2 to 5 years old** | Active | → CHANGE PROFILE

CHOOSE NUTRIENTS

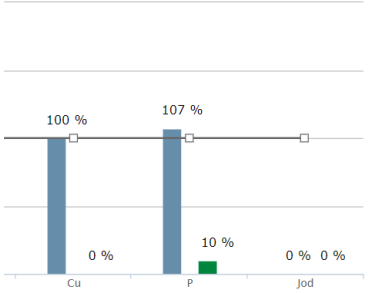
Choose what you want to compare	Weight	kJ	kcal	Fat	Omega-3	Omega-6	Cholesterol	Carbohydrates incl fibre	Starch	Mono+Disacc	Sugar, added
Daily recommendations		**5461 kJ**	**1305 kcal**	**36.3 - 58 g (25 - 40 E%)**	**< 1.5 g (1 E%)**	**< 7.3 g (5 E%)**	-	**152.3 - 203.8 g (45 - 60 E%)**	-	-	**< 32.6 g (< 10 E%)**
✖ Cornmeal	364 gram	5613 kJ	1325 kcal	8.4 g	0.11 g	3.64 g	0 mg	302.1 g	277.004 g	3.3 g	0 g
✖ Corn starch	355 gram	5361 kJ	1260 kcal	0 g	0 g	0 g	0 mg	315.2 g	315.24 g	0 g	0 g
CHOOSE FOOD ITEM	-	-	-	-	-	-	-	-	-	-	-



Fibre	Protein	Salt	Vit A	Retinol	B-carotene	Vit D	Vit E	Vit B1	Vit B2	Niacin	Vit B6	Folate	Vit B12	Vit C	Ca	Fe	Na	K
11 - 16 g	**32.6 - 65.3 g (10 - 20 E%)**	**< 3.5 g**	**350 RAE**	-	-	**10 µg**	**5 alfa-TE**	**0.6 mg**	**0.7 mg**	-	**0.7 mg**	**80 µg**	**0.8 µg**	**30 mg**	**600 mg**	**8 mg**	**< 1400 mg**	**1800 mg**
22 g	21.8 g	0 g	33 RAE	0 µg	400 µg	0 µg	4 alfa-TE	0.51 mg	0.18 mg	3.6 mg	0.36 mg	36 µg	0 µg	0 mg	7 mg	5.5 mg	0 mg	662 mg
0 g	0 g	0 g	0 RAE	0 µg	0 µg	0 µg	0 alfa-TE	0 mg	0 mg	0 mg	0 mg	0 µg	0 µg	0 mg	28 mg	0.4 mg	21 mg	18 mg
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-



Mg	Zn	Se	Cu	P	Jod
120 mg	**6 mg**	**25 µg**	**0.4 mg**	**470 mg**	**90 µg**
193 mg	3.6 mg	0 µg	0.4 mg	502 mg	0 µg
7 mg	0 mg	0 µg	0 mg	46 mg	0 µg
-	-	-	-	-	-



Calculation for a 5 year old girl:

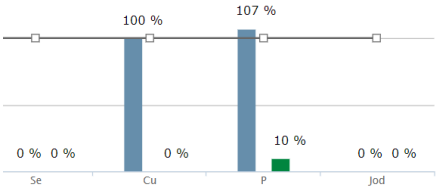
For 5 year old girl: taking the 0 z-score on a weight for age chart from WHO, we will use 18 kg as calculating weight.

- Henry's basal metabolic rate equation: (23.3 x (weight=18)) + 514 = 933kcal
- PAL 5y old girl 1.50 (213)
- 933*1.50
- 90% = 1259.6 kcal

Cornstarch 354.8 gr / day 90% of daily requirement

Cornmeal 345.9 gr / day for 90% of daily requirement

	K	Mg	Zn	Se	Cu	P	Jod
	1800 mg	**120 mg**	**6 mg**	**25 µg**	**0.4 mg**	**470 mg**	**90 µg**
	662 mg	193 mg	3.6 mg	0 µg	0.4 mg	502 mg	0 µg
	18 mg	7 mg	0 mg	0 µg	0 mg	46 mg	0 µg
	-	-	-	-	-	-	-

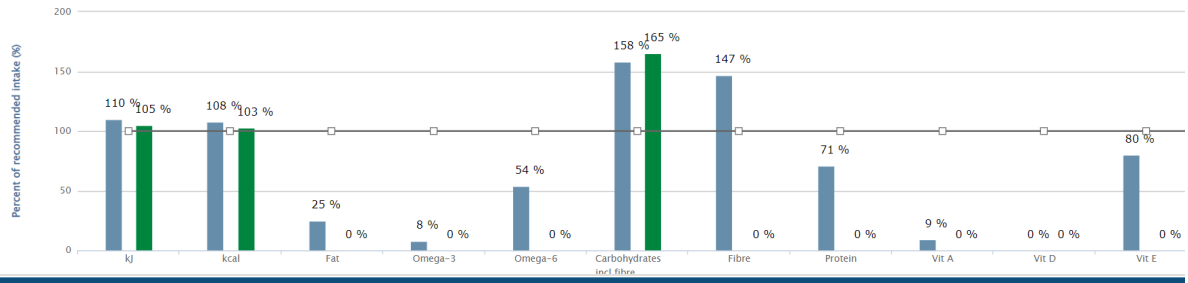


CHOSEN PROFILE

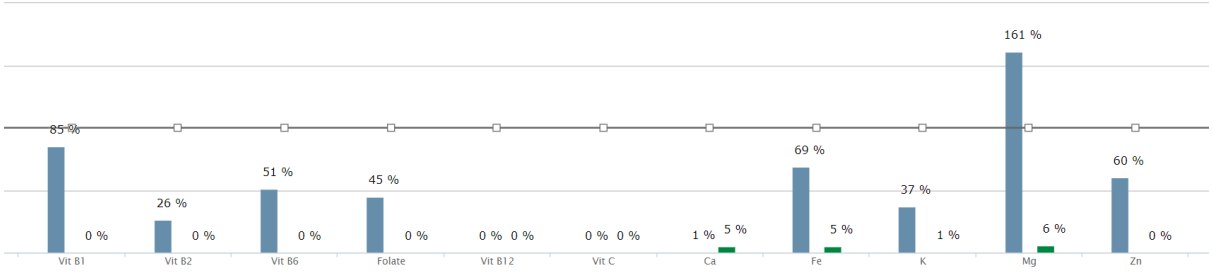
Girl | **2 to 5 years old** | Active | → CHANGE PROFILE

CHOOSE NUTRIENTS

Choose what you want to compare	Weight	kJ	kcal	Fat	Omega-3	Omega-6	Cholesterol	Carbohydrates incl fibre	Starch	Mono+Disacc	Sugar, added
Daily recommendations		**5113 kJ**	**1222 kcal**	**33.9 - 54.3 g (25 - 40 E%)**	**< 1.4 g (1 E%)**	**< 6.8 g (5 E%)**	-	**142.5 - 190.8 g (45 - 60 E%)**	-	-	**< 30.6 g (< 10 E%)**
✖ Cornmeal	364 gram	5613 kJ	1325 kcal	8.4 g	0.11 g	3.64 g	0 mg	302.1 g	277.004 g	3.3 g	0 g
✖ Corn starch	355 gram	5361 kJ	1260 kcal	0 g	0 g	0 g	0 mg	315.2 g	315.24 g	0 g	0 g
CHOOSE FOOD ITEM	-	-	-	-	-	-	-	-	-	-	-



Fibre	Protein	Salt	Vit A	Retinol	B-carotene	Vit D	Vit E	Vit B1	Vit B2	Niacin	Vit B6	Folate	Vit B12	Vit C	Ca	Fe	Na
10 - 15 g	**30.6 - 61.1 g (10 - 20 E%)**	**< 3.5 g**	**350 RAE**	-	-	**10 µg**	**5 alfa-TE**	**0.6 mg**	**0.7 mg**	-	**0.7 mg**	**80 µg**	**0.8 µg**	**30 mg**	**600 mg**	**8 mg**	**< 1400 mg**
22 g	21.8 g	0 g	33 RAE	0 µg	400 µg	0 µg	4 alfa-TE	0.51 mg	0.18 mg	3.6 mg	0.36 mg	36 µg	0 µg	0 mg	7 mg	5.5 mg	0 mg
0 g	0 g	0 g	0 RAE	0 µg	0 µg	0 µg	0 alfa-TE	0 mg	0 mg	0 mg	0 mg	0 µg	0 µg	0 mg	28 mg	0.4 mg	21 mg
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-



Annex 9: On the author

There are several reasons that motivated me at this moment to look at the problem of climate change impacting child health in a holistic way. During my medical school I was involved in research about perinatal health outcomes and social deprevation which opened my eyes to the broad context that plays a role in health outcomes. During my professional work this kept playing an important role, in my further training and studies and eventually now leading up to my study for Master in International Health. It has shown me the benefit of looking at health problems using this view and at this moment the planetary health view / approach is the one that seems very good at doing this and able to communicate this effectively. The priorities of public health research have to shift into also taking into account the effects on and off the broader environment.

Therefore when I look at the selected analytical framework there are some important lenses I miss, mostly the ones that address the (lack of) capital on a household level and on the broader socio-economic determinants of health which play a major effect in safe motherhood and early childhood development.

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