GOVERNMENT OF MALAWI

National Adaptation Plan Readiness Project in Malawi – Climate change modelling and climate change risk assessment consultancy

Climate Risk Assessment Report

November 2023

Commenté [LP1]: General comment: could you integrate more elements on CC impacts on wildlife? This is a priority sector identified by the Government, and features in the list of priority sectors of the ToRs.

Commenté [LF2R1]: Done altho wildlife was never one of our featured sectors so we did not address it during the inception or field mission

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List of Abbreviations

ADC – Area Development Committee

ADD – Agricultural Development District

ARV – Anti-retroviral (drugs)

BoM – Bureau of Meteorology (Australia)

CAB – Congo Air Boundary

CAF – Cancun Adaptation Framework

CBD - Convention on Biological Diversity

CIAT - International Center for Tropical Agriculture

CoP – Congress of Parties

CRA – Climate Frisk Assessment

DCCMS – Department of Climate Change and Meteorological Services (Government of Malawi)

DCPC – District Civil Protection Committee

DDC – District Development Committee

DoDMA – Department of Disaster Management Affairs (Government of Malawi)

DoF – Department of Fisheries

DRM – Disaster Risk Management

DRR – Disaster Risk Reduction

EAD – Environmental Affairs Department (Government of Malawi)

EGENCO- Electricity Generating Company (of Malawi)

ENSO – El Niño Southern Oscillation System

EPA – Extension Planning Area

FAO – Food and Agriculture Organisation

FAW – Fall Army Worm

FGD – Focus

FISP - Farm Input Subsidy Programme

FRA – Flood Risk Assessment

GCF – Green Climate Fund

GCM – General Circulation Model

GFDRR = Global Facility for Disaster Risk Reduction

GDP - Gross Domestic Product

GoM – Government of Malawi

GVH – Group Village Head

IOD – Indian Ocean Dipole

IFRC – International Federation of the Red Cross

IPCC – Intergovernmental Panel on Climate Change

ITCZ – Inter-Tropical Convergence Zone

LEG – Least Developed Countries Group

LMOT – Lake Malawi Outflow Threshold

LMSRB – Lake Malawi - Shire River Basin

MFR – Meteo-France

MoA – Ministry of Agriculture

$MtCO_2e$ – Metric tonnes of Carbon Dioxide - equivalent

NAP – National Adaptation Plan

NAPA – National Adaptation Programme of Action

NDC – Nationally Determined Contribution

NLDP – National Livestock Development Policy

NSO – National Statistics Office

ppn – Precipitation

PPP – Purchasing Power Parity

RCM – Regional Circulation Model

RCP – Representative Concentration Pathway

sEA – Southern East Africa

SPEI – Standardised Precipitation Evapotranspiration Index

SPI – Standardised Precipitation Index

SSP – Shared Socio-Economic Pathway

SST – Sea surface temperature

TA – Traditional Authority

ToRs – Terms of Reference

UNDRR – United Nations Office for Disaster Risk Reduction

UNEP – United Nations Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

UN-OCHA – United Nations Office for the Coordination of Humanitarian Affairs

USAID – US Agency for International Development

VDC – Village Development Committee

1: Introduction

Climate Risk Assessments identify the likelihood (frequency and intensity) of climate hazards and their potential impacts for specified geographic entities, in this case a country and its districts. This is a fundamental step in informing and assessing the need for climate action and investment and strategising climate adaptation and building of resilience.

The principal objective of this task is to compile a government-validated climate risk assessment (CRA) for the predominant climate hazards affecting Malawi (storm, flood, heat and drought), both nationally and articulated through eight designated districts, one from each of the eight Agricultural Development Districts (ADDs) of the country. The CRA takes place across the entire social ecological system (supporting an ecosystem-based approach [EbA]) but prioritising a given set of sectors – agriculture – crop production, agriculture – livestock, forestry, fisheries, infrastructure, and water. Other sectors are captured through the prism of the prioritised sectors, especially health and energy whilst special attention is also given to gender and marginalised groups.

Germane to the methodology for the CRA was to establish early dialogue with principal government and non-government actors and with representatives from the affected communities in each of the 8 districts. With that in mind an early element in the process was to undertake an Inception Field Mission (10-14 October 2022) during which a variety of Government ministries and departments were visited, and directors interviewed in order to elicit their views of both the work and the conditionalities applying to climate and development in Malawi and to canvass their support for the tasks ahead in gathering data and information.

Ministries and departments consulted included Land Resource Conservation (DLRC), Environmental Affairs (EAD), Disaster Management, Agriculture, Water Affairs, Forestry, Fisheries, Gender, Health and the Department of Climate Change and Meteorological Services (DCCMS) a partner department in the compilation of data for the CRA. Visits were also paid to leading supranational agency offices that deal on a day-to-day basis with climate related development issues in the country including the United Nations Development Programme (UNDP) country office and the Food and Agriculture Organisation (FAO) country office. A consultation also took place with a leading national civil society organisation, the Civil Society Network on Climate Change (CISONNEC). During the field mission week, a field visit was also made to the District Council of Chikwawa, one of the focus districts for the CRA.1

A field mission, organised by the commissioning Government Agency for this work – the Environmental Affairs Department (EAD) of the Government of Malawi, was conducted (13 July to 04 August 2023) to the eight focus districts of the CRA in which 'participative risk assessments' were carried out by way of 8 workshops, held, one in each district and, during which, field visits were made to sites of climate exigency and current adaptation activities and to meet and discuss with communities and organisations involved in productive livelihoods.2 The outputs of these interactions have informed this report as has the 'Climate Projections for the Eight Agricultural Development Divisions in Malawi,'

1 'Inception Field Mission Report: Advancing the National Adaptation Plan (NAP) Process: Climate Resilience for Sustainable Development in Malawi: Producing Climate Change Scenarios and Risk Assessment, November 2022

2 'Malawi CRA Field Reports for EAD,' October 2023. 'NAP-Climate Risk Assessment: Field Mission 16 July to 04 August 2023, Director's Debriefing,' August 2023. 'Malawi NAP-CRA: Field Mission 16 July to 03 August 2023 Preliminary Briefing 04 August 2023.'

produced by the Malawi Department for Climate Change and Meteorology (DCCMS), October 2023 which supports and accompanies this document.3

In the last few decades, Malawi has experienced multiple severe droughts, extreme heat events (mainly in the south), heavy storms and fluvial/pluvial flooding events which have had a significant impact on the country's social economy, including productive sectors such as agriculture, fisheries and forestry, energy provision, infrastructure, and food security. Over the last half century both the number and extent of floods and droughts have increased sharply. This work takes on priority status and must be a vital contributor to the creation of the Malawi National Adaptation Plan (NAP) which seeks to enhancet climate resilience, to minimise and manage the impact of future climatic shocks and to climate-proof development plans such as Malawi 2063.4

The process employed in this CRA has been to

1. conduct early dialogue with all partners;
2. construct an Inception Report with Methodology that would be validated by the Government of Malawi through its Expert Working Group on Adaptation (EWGA) (8 December 2022);
3. await revision of ToRs to reflect an expanded remit;
4. create an updated Inception Report accompanying -
5. a set of Impact Storylines that put flesh on the real-life experience of climate change and extreme weather in Malawi;
6. implement a Field Mission to Malawi to the 8 District featured for focus study to carry out a Participative Risk Assessment featuring an impact analysis from which factors of vulnerability and exposure are gleaned from which recommendations for Adaptation were developed (which will feature in the later Adaptations Options Reports);
7. compile a climate risk Assessment which combines the work of defining climate and weather to date along with projections for the future with both an impact analysis and an assessment of the scale of risk in future climate scenarios.

This process follows the agreed methodology referred to above and also adheres to the procedure laid out in 'Malawi's National Adaptation Plan Framework,' Government of Malawi, 2020, especially paragraphs in 7.1.3 pp. 23-24, 'Carry Out Climate Change Risk and Vulnerability Assessments' and with additional guidance provided by the United Nations Environment Programme, acting on behalf of the Government of Malawi as Task Manger for this work.

This document will be followed by an Adaptation Options Report x 8 for each District and will be summarised in a User-Friendly Brief for Policymakers

3 Both the EAD and DCCMS are component entities of the Malawi Ministry of Natural Resources and Climate Change.

4 'Malawi 2063: Malawi's Vision - An Inclusively Wealthy and Self-reliant Nation,' National Planning Commission, Lilongwe, 2020.

2: Climatological analysis

Malawi has a sub-tropical continental climate characterised by two distinct seasons: a rainy season from November to April and a dry season from May to October. Average daily temperatures vary with seasons and elevation, with the coldest temperatures (6-10°C) in July in the Mulanje Highlands and the hottest (35–36°C) in October in the Lower Shire Valley. Maximum temperatures in the Lower Shire Valley have been breaking records in recent years, often exceeding 40 and reaching as high as 46^{o} C. Annual precipitation can vary from as little as ≤600mm per annum along the Rift Valley floor (shore of Lake Malawi) and the Lower Shire Valley to ≥2500mm (World Bank 2021), and more in some highland areas over 1300 m (see Figure 1). Overall, rainfall exhibits considerable interannual variability and is highly influenced by the inter-tropical convergence zone (ITCZ) together with the Congo Air Boundary (CAB), El Niño Southern Oscillation (ENSO) including the La Nina phenomenon and Indian Ocean Dipole (IOD), the southern Indian Ocean Mascarene High, variability in the water levels in the country's major lake – Lake Malawi, and the broader hydrological network (GoM 2019).[5]

5 GoM (2019) Malawi 2019 Floods Post Disaster Needs Assessment (PDNA) found online at https://reliefweb.int/report/malawi/malawi-2019-floods-post-disaster-needs-assessment-report

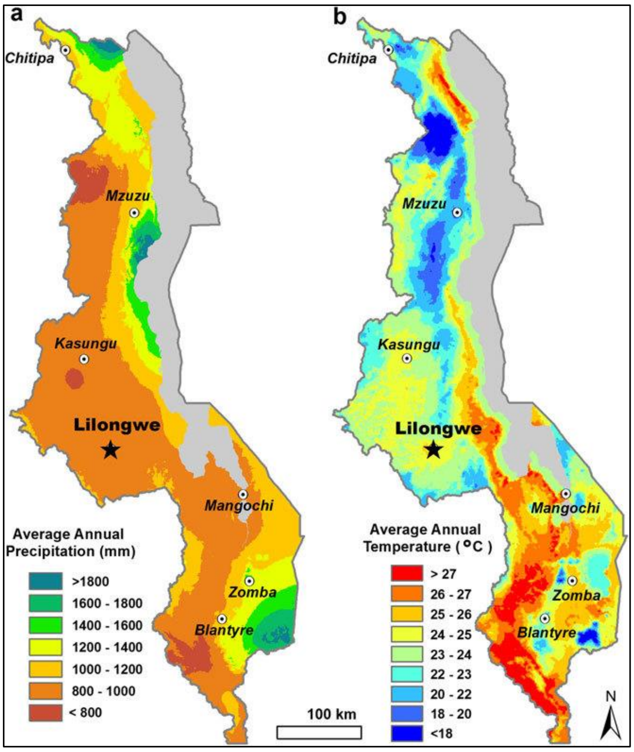

Figure 1. Malawi – a: average annual precipitation; b: average annual temperature, both over land surface (Li 2017)[6]

[6] Li, G et al (2017) 'Mapping land suitability for agriculture in Malawi,' *Land Degradation and Development*, Feb 2017 issue

All three regions in Malawi (North, Central and South) lie in the Tropical wet and dry or savannah climate zone (Köppen: Am, Aw, Bsh, Cwa, Cwb – see Figure 2)

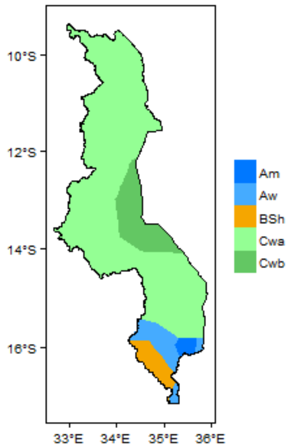

Figure 2. Climate zones of Malawi: Am – tropical monsoon, Aw – tropical savannah, Bsh – arid steppe (hot), Cwa – temperate with dry winter and hot summer, Cwb - temperate with dry winter and warm summer (reproduced courtesy of the British Geological Survey (BGS)

Like other southeast African countries in the latitudinal zone between the Tropics of Cancer and Capricorn, Malawi's climate is largely influenced by the seasonal migration, north and south of the equator, of the Inter-Tropical Convergence Zone (ITCZ), a low-pressure belt around which the North East and South East Trade Winds converge, and by the variability of moisture transport from the Indian Ocean onto the continental land mass. The ITCZ brings seasonal rains in the single rainy season to countries such as Malawi, which lies at the southern end of its trajectory. Its movement is mediated in southern central Africa by the Congo Air Boundary (CAB), a convergence zone that marks the confluence of Indian Ocean air with unstable air from the Congo Basin and also by a semi-permanent subtropical high-pressure zone in the South Indian Ocean called the Mascarene High. This, in turn, is affected by sea surface temperature (SST) anomalies such as the Indian Ocean Dipole (IOD) and the El Nino Southern Oscillation (ENSO) system.[7]

Recent research postulates that the Lake Malawi catchment has experienced rapid natural climate change over the last 140K years combined with tectonic movement and that the lake has morphed from a rather tiny body of water in the centre of what it is now into the lake we see today as a result of a shift from a very dry, drought prone climate to one of heavy seasonal rains.[8] Combined with anthropogenically generated climate forcing, this makes climate prediction a complex practice full of

7 The IOD is one aspect of the general cycle of global climate, interacting with similar phenomena like the El Niño-Southern Oscillation (ENSO)

8 Wright, L. J. M., & Scholz, C. A. (2023) 'Spatio-temporal variations in sediment delivery as a response to rapid quaternary climate change in the Lake Malawi Rift, East Africa,' *Journal of Geophysical Research: Earth Surface*, 128, found online at https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2022JF007027

uncertainties, hence the response to such uncertainty needs to be especially inclusive of possible wide variations in weather in the future.

Vignette 1: Malawi as a climate transition zone

Siderius 2021 et al consider the southern East Africa (sEA) sub-region (including southern Tanzania and Malawi) to be a ''climate transition zone'' (these exist throughout the world as liminal zones between adjacent regimes of the components that create the climate (atmosphere, lithosphere, cryosphere, biosphere and hydrosphere) and explain this in three aspects:

1. Regarding rainfall variability, sEA lies in a transition zone of complex responses to dominant global and regional modes of climate variability related to two opposing elements of the El Nino-Southern Oscillation (ENSO), specifically El Nino and La Nina. When an El Nino phase is in the ascendency, an area of high sea surface temperatures (SSTs) forms in the western Indian Ocean off the coast of East Africa – this is referred to as a positive phase of the Indian Ocean Dipole (IOD) and brings increased rainfall to East Africa as far south as northern Malawi; conversely, the southern Region of the country, especially the low -lying Shire River Valley (SRV) may suffer drought and extreme warm temperatures as is happening in October 2023) and drought. By contrast, when the opposite component of ENSO, La Nina forms (when the IOD forms a heat gradient warming to the eastern Indian Ocean, referred as its negative phase),9 drought may come to East Africa while another area of warm SSTs forms in the southern Indian Ocean catalysed by a high pressure anticyclone called the Mascarene High which drives storms and cyclones into the southern part of sEA and affects the Southern and Central Regions of Malawi with storms and flooding as happened in 2022 and 2023 with Tropical Storm Ana and Cyclone Freddy respectively, while the Northern region, by contrast, suffers dry spells and even drought as happened in 2023 to Karonga District which suffered failure of the rice crop.
2. sEA straddles the transition between the bimodal rainfall regimes of equatorial East Africa to the north and the unimodal southern African regime. Kumbuyo (2015) and Wood and Moliniere (2013) say that Malawi straddles both equatorial east Africa (north of 10°S) and subtropical southern Africa (south of 15°S), and that the northern and southern regions of Malawi are influenced by different climate drivers.10 Thus, there are two peaks to the rainy season in Karonga and south along the lake coast at least as far as Nhakta Bay.11 This is articulated by a longer more spread out rainy season in the north of Malawi and the more concentrated shorter rainy season in the south, which generally receives less rainfall overall.
3. Third, there is low inter-model agreement in rainfall projections for sEA. This contrasts with the relatively robust projected change (decrease) over the neighbouring Eastern Southern Africa to the South. In effect, that means less certainty as to what to expect in terms of rainfall projections for the future (as is demonstrated by the DCCMS Projections for rainfall produced for this work),12 compared, for example, to temperature models where there is considerably more agreement (increase).

Based on the logic expounded in Vignette 1, the balance of scientific opinion, confirmed by the evidence gathered by this work, shows that there are two sets of climate drivers affecting the weather

9 The IOD actually refers to portions of the Ocean in which there is a gradient of cooler to warmer surface waters. In the positive phase, the gradient forms in an east to west manner, warmer waters being found in the west. In a negative phase, the gradient is reversed.

10 Wood, L. and Morinière, L., 2013. 'Malawi Climate Change Vulnerability Assessment,' USAID and Kumbuyo C.P. et al (2015) 'Linkage between Malawi Rainfall and Global Sea Surface Temperature,' *Journal of Rainwater Catchment Systems*, 20, 2, 7-13

11 Kumbuyo, C.P. et al (2015) 'Linkage between Malawi Rainfall and Global Sea Surface Temperature,' *Journal of Rainwater Catchment Systems*, 20 (2): 7-13.

12 DCCMS (2023) 'Climate Projections for the Eight Agricultural Development Divisions in Malawi,' Blantyre.

and climate in Malawi. The Northern Region is affected more by the ITCZ interacting with the Congo Air Boundary (CAB) (which is a weather system controlled by the meeting of air currents from both the southeast Atlantic and the northern Indian Ocean) and the influence of ENSO variation articulated also by the Indian Ocean Dipole (IOD). The Southern Region is affected by a weaker ITCZ and strongly by the influence of SSTs in the southeast Indian Ocean. The aforementioned writers also do not consider that ENSO has much influence on weather in the Southern Region but this CRA argues to the contrary, that ENSO does indeed have an influence and has a direct impact on weather in the south as is evidenced by the tropical storms that impacted the Southern Region during 2019 and all three consecutive years of La Nina years rainfall seasons of 2020-2021, 2021-2022, and 2022-2023.

Thus, when projecting future climate and assessing likely risk of impacts and increasing vulnerability and exposure and, from that analysis, subsequent adaptation plans for the NAP, it is important that these different sets of climate drivers are considered.

Thus, there is a clear distinction between the wetter season (November to March) with weather dominated by low pressure air, ascending with wind blowing in a clockwise direction and the dry season – April to October with weather mediated by high pressure descending anti-cyclonic air with wind blowing in an anti-clockwise direction (see Figure 3 below). This is reflected in the distribution of rainfall throughout the year in Figure 4 which also displays average temperatures.

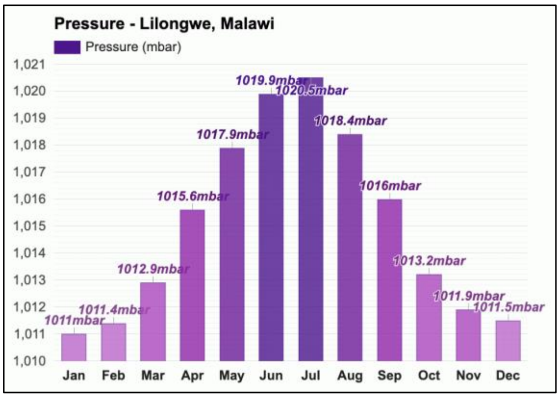

Figure 3. Chart of average barometric pressure recorded at Lilongwe, Malawi. The low-pressure rainy season (Oct-Mar) can be clearly observed with pressure less than 1013 mbar contrasting with the higher-pressure dry season (Apr-Sept)[13]

[13] https://www.weather-atlas.com/en/malawi/lilongwe-climate

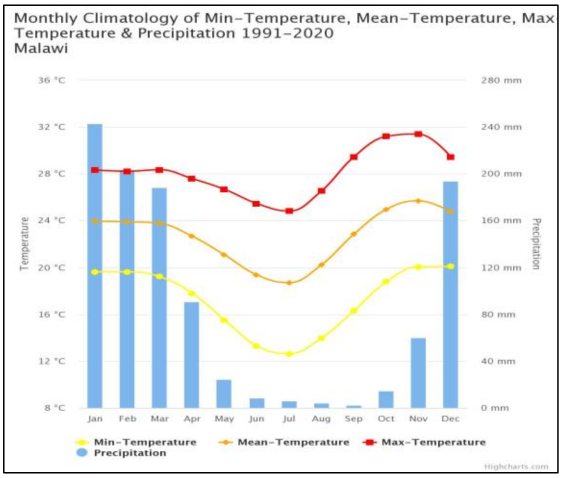

Figure 4. Distribution of rainfall and temperature variation (max, min and mean) throughout the year for Malawi (World Bank 2021)

Subtropical anticyclones (high pressure air masses) have a vital role in the short-term weather variations in extra-tropical regions (Xulu et al 2020).14 The Mascarene High goes through weakening and strengthening phases according to the variation in SSTs (linked to different ENSO phases) while the persistent trade winds of the tropics blow out of the subtropical anticyclones and can transport moisture from hot-spots over the oceans onto the continents (driven by the aforementioned trade winds blowing from east to west into SE Africa).

Strong La Niña phases are associated with wet years in the Southern and Central Regions and dryer weather in the Northern Region, even though causal connections remain to be fully understood (Gergis and Fowler 2009).15 Strong El Niños, where warm SSTs flow from west to east, conversely, mostly coincide with dry years in Southern and Central Regions of Malawi (though wet in northeast Africa and in the Northern Region of Malawi). Sometimes, these oppositional ENSO events follow one another alternatively such as the strong La Nina exemplified by storms and flooding throughout Malawi in 2015 (from Tropical Storm Chedza) followed immediately afterwards in 2016 by extreme drought as a result of an El Niño phase, one of the deepest droughts that Malawi has ever endured. More recently, La Nina phases seem to have become more frequent and in the 3 consecutive rainy seasons from 2021 through to 2023, La Niña phases have been in the ascendency. The inter-annual variability and uncertainty implied by this is indicative of the difficulty in making long term climate and weather projections for Malawi. Table 1 lists the most devastating, cyclonic events since 2000. It is immediately clear that cyclonic activity, all originating in the Indian Ocean, is increasing in frequency, especially affecting the South of the country which has become a vulnerability hotspot for both storm and drought. As will be seen in the following sections, the ramifications – cascading impacts - of that for

14 Xulu, N.G. et al (2020) 'Climatology of the Mascarene High and Its Influence on Weather and Climate over Southern Africa,' *Climate*, 8 (7), 86

15 Gergis, J.L. and Fowler, A.M. (2009) 'A History of ENSO Events Since A.D. 1525: Implications for Future Climate Change,' *Climatic Change*, 92, 3, 343– 87.

the social ecological system (SES) and on Malawi's development ambitions are becoming such that the SES or ecosystem balance can be irretrievably changed and development plans thwarted.

Table 1. Tropical storms and cyclones directly affecting Malawi since 2000.[16]

Tropical Storms and Cyclones affecting Malawi since 2000		
Name	**Date**	**Regions affected**
Tropical Storm Astride	03 January 2000	Southern
Tropical Storm Delfina	31 December 2002	Central, small parts of Northern and Southern
Cyclone Funso	21 January 2012	Southern
Tropical Storm Chedza	14 January 2015	Southern, south Central
Cyclone Dineo	15 February 2017	Southern
Cyclone Idai	4-16 March 2019	Southern
Chalane	20 Dec 2020 to 4 Jan 2021	Southern
Tropical Storm Ana	23-25 January 2022	Southern, south Central
Cyclone Gombe	8-14 March 2022	Southern
Cyclone Freddy	2-14 March 2023	Southern, south Central

In Vignette 2, the increasing relevance of the La Nina component of the ENSO phenomenon is set out. The influence of La Niña phases on the weather pattern for Malawi and for the SES and productive activity are becoming increasingly evident. However, the risk of intermittent deep droughts from deep El Niño phases must, equally, be expected to increase.

[1616] https://www.worlddata.info/africa/malawi/cyclones.php

Vignette 2: La Niña – explanation and relevance for Malawi

Up to the last decade the ENSO phenomenon has been dominated by El Ninos sometimes of multi-year duration interspersed with occasional, reverse phenomenon La Nina phases, but this has been observed to change with the La Niña phase becoming more pronounced and of longer duration. During the last 3 rainy seasons 2020-21, 2021-22 and 2022-23, there has been a succession of three La Nina periods.

La Nina is part of the El Nino Southern Oscillation (ENSO) as is El Nino itself. During a La Niña phase, strong winds blow warm surface water from east to west across the oceans. The sea surface temperature across the eastern equatorial part of the central to eastern Pacific Ocean will be lower than normal by 3–5 C whereas the western side warms up by a similar amount. The same process takes place in the Indian Ocean, meaning that warmer seas surface temperatures (SSTs) prevail of the coasts of Tanzania, Madagascar and in the Mozambique Channel.

These warm SSTs tend to attract tropical storms and cyclones which form in mid-ocean then deepen, gaining strength by sucking up warm water, tracking westwards and barrelling into Madagascar where they deposit some water in extreme storms then repeating the process across the Mozambique Channel and into Mozambique where there is a tendency to encounter warm landward winds which often divert the cyclonic track north-westwards into southern Malawi.

These storms, though they have lost strength since crossing the Mozambique coastline and dropping water, still pack enough strength to cause extreme rain events resulting in floods and loss and damage to lives, livelihoods and infrastructure from south to north through Malawi with the southern region being worst affected. An appearance of La Niña often may last five months or more, increasing the risk of untimely storm related disasters outside of the rainy season.

Some writers have suggested that the longstanding notion of an Inter-Tropical Convergence Zone (ITCZ) is giving way to the looser concept of formulation of a rain belt that moves south to affect Malawi in the hot season from October to April and returns north during the southern hemisphere's winter leaving Malawi with little rainfall from other weather systems from May to October.17 Cloud formation results from both local conditions, affected by topography, and from events in the distant Indian Ocean. Clarence-Smith (2022) proposes that the interplay between the Mascarene High (anticyclone) and the Angolan Low (depression), which forms around the Angolan Highlands during the hot season, and draws in moist air from the Indian Ocean.18 When a deep Angolan Low coincides with an enhanced Mascarene High, trade winds blow forcefully from the Indian Ocean, and precipitation increases markedly (Xulu et al 2020). Remains of Indian Ocean cyclones may then sweep far inland from Late December through to March (see Table 1) with consequent effects and impacts on countries such as Malawi, a trend that has been increasing, particularly since 2000.

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17 Clarence-Smith, W.G. (2022) Rainfall and Floods in the Upper Zambezi Basin, 1680s to 1910s. In: Gooding, P. (eds) *Droughts, Floods, and Global Climatic Anomalies in the Indian Ocean World*, Palgrave Series in Indian Ocean World Studies. Palgrave Macmillan, Cham, London and https://www.noaa.gov/jetstream/tropical/convergence-zone#:~:text=The%20Inter%2DTropical%20Convergence%20Zone%20(ITCZ)%20appears%20as%20a,broken%20into%20smaller%20line%20segments.

18 Ibid

As noted above, the most vulnerable region in Malawi to tropical cyclones is the Southern Region, partly by virtue of its low elevation above sea level. As explained in the climatology section, storms are regularly blown inland from the Indian Ocean in the northern half of Mozambique, quite often close to the delta of the Zambezi River and track westwards until they run out of energy through lack of warm surface water to suck up as fuel. Figure 5 is adapted from a satellite image showing Tropical Storm Ana on the day it arrived over southern Malawi. The cloud pattern provides a typical example of the route taken by storms fomenting over the Indian Ocean. Even though cyclones lose strength as they track over land, they can still arrive with considerable force, depositing large quantities of rainfall, causing extensive loss and damage. Since 2015, the country has experienced cyclones of high magnitude all bringing excessive rainfall resulting in primary impacts such as storm damage caused by wind and rain, fluvial and pluvial flooding, and land and mud slides.

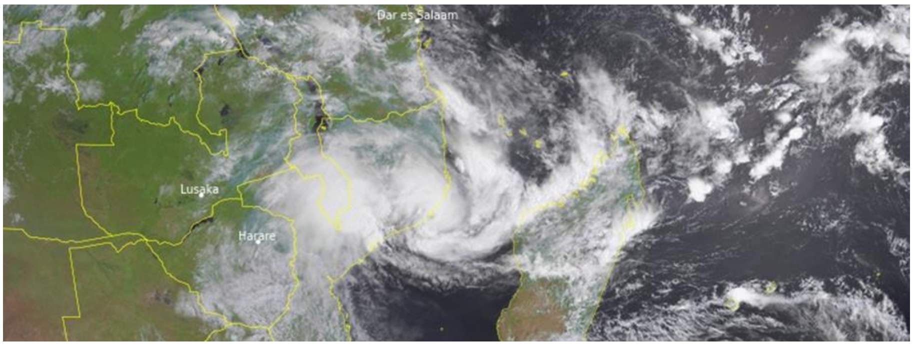

Figure 5. Image of Tropical Storm Ana, taken on January 24th, the day it unleashed high winds and torrents of rainfall on southern Malawi.[19]

Recent studies have shown that several linked factors (ITCZ, CAB, Indian Ocean SSTs and ENSO) are the mediating influences over rainfall and drought in Malawi (Kambuyo et al 2015, Tierney. et al 2011).20 What this summary of views from climatologists all agree on, however, is that annual variations in the pattern of rainfall (and drought) over Malawi, are influenced first by increasing irregular migration of the ITCZ and secondly, by fluctuations in the Indian Ocean and Indo/Pacific ocean-atmosphere dynamics that dominate climate in south east Africa, including Malawi (any influence from the Atlantic influence being constrained due to orographic factors) (Sepulchre et al 2006). What is also clear, is that the occurrence of extreme rainfall and drought events, especially the former, with consequent effects on lives and livelihoods is increasing in both frequency and intensity and with less predictability, the ramifications of which are examined in the section on climate hazards and impacts.

Whilst the objective of this paper is to discuss climatology to date before recording and identifying climate projections in the CRA, it may be useful to briefly illustrate changes to date and estimated (see Table 2).

19 https://watchers.news/2022/01/24/tropical-cyclone-ana-makes-landfall-over-mozambique/
20 Kumbuyo, C.P. et al (2015) 'Linkage between Malawi Rainfall and Global Sea Surface Temperature,' *Journal of Rainwater Catchment Systems*, 20 (2): 7-13. Tierney, J.E. et al (2011) 'Late Quaternary behavior of the East African monsoon and the importance of the Congo Air Boundary,' *Quaternary Science Reviews*, 30 (7–8): 798-807.

Table 2. Climate observations since 1960 and projected changes

Historical climate since 1960 (source USAID)[21]	**Projected changes in climate (2040s, 2060s 2080s)**[22]
• Temperature increases of approximately 0.9°C, with the most rapid increase in summer months (Dec–Feb), between 1960 and 2006. • Increase in the number of days (+30 days) and nights (+41 days) considered "hot." • Highly variable year-to-year rainfall totals with no statistically significant trends. • Increased length of dry spells during the rainy season. • Increased intensity, frequency and magnitude of floods and droughts.	• Higher average temperatures of 2–3°C by the 2080s, with largest increases in early summer months. • Increase in the number of days of extreme heat - >35° C and groups of days (heatwave). • Overall increases or decreases in rainfall difficult to project. • Later onset/earlier cessation of rainy season. • Increase in average monthly rainfall from Dec–Jan and a decrease from Feb–April. • Increases in the proportion of rainfall during extreme events

a. Rainfall

In Figure 6, the predicted mean rainfall for Malawi for the present and future is presented. DCCMS reports that the future rainfall changes are uncertain, as 67% of the models indicate a decreasing trend of rainfall from 2040s to 2080s for SSP2.45 scenario, while with the SSP5.85 scenario, more models (67%) indicate a decreasing trend during the 2040s, but the dimensions change during 2060s and 2080s where more models (67%) indicate an increasing trend. The ensemble mean of the models cancel each other out hence not much change is noted in Figure 6 among the 2020s, 2040s, 2060s and 2080s for both scenarios.

[21] USAID (2017) Climate change risk profile fact sheet - Malawi
[22] DCCMS (2023)

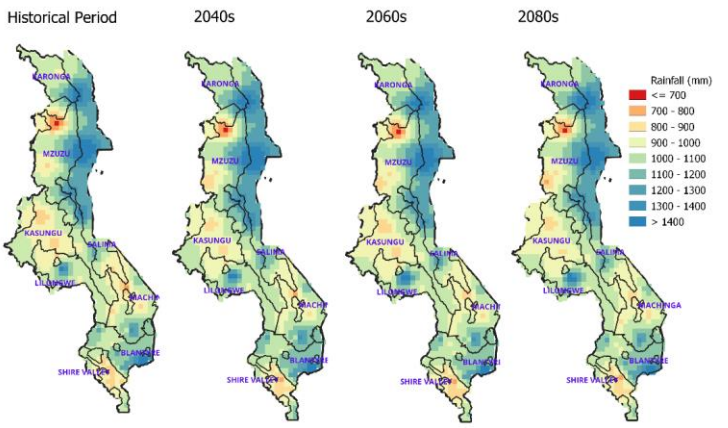

Figure 6A. The ensemble annual rainfall mean from 2020s (historical period) to 2040s, 2060s and 2080s based on a better case scenario – SSP2.45. The eight ADDs are overlain on the distribution (DCCMS 2023).

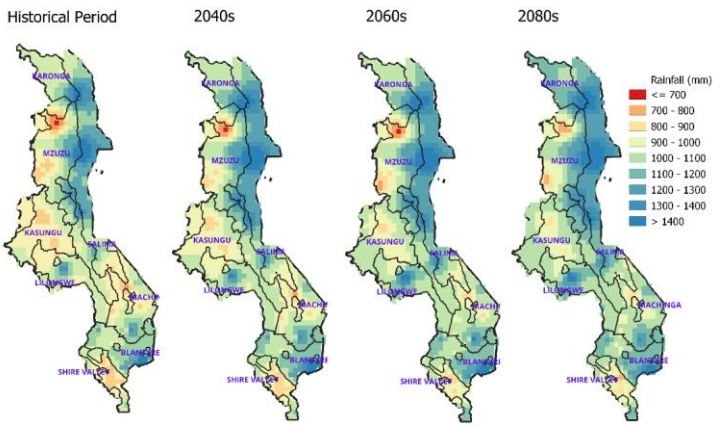

Figure 6B. The ensemble annual rainfall mean from 2020s (historical period) to 2040s, 2060s and 2080s based on a better case scenario – SSP5.85. The eight ADDs are overlain on the distribution (DCCMS 2023)

b. Temperature

The spatial status of mean temperature is presented in Figures 7 and 8 below based on the mean generated from all models (DCCMS 2023). The temperature changes with reference from 1991-2020 are also shown in Table 3. Like the maximum temperature, the warmest Agricultural Development District [also sometimes named Divisions] (ADD) is the Shire Valley and coolest is Lilongwe. On average, the mean temperature in Malawi is 22.6 ° C. The mean temperature is expected to increase by about +0.4 ° C on average for the SSP2.45 and +0.7 ° C for the SSP5.85 during the 2040s. But the individual models indicate the range between +0.2 and +1 ° C.

Commenté [LP3]: I suggest to provide the reference from the beginning rather than under the figures

Commenté [LF4R3]: Done

Commenté [LP5]: Could you please explain what's ADD?

Commenté [LF6R5]: Also spelt out on page 8 and in the List of Abbreviations. We were asked to consider the country thru these 8 ADDs which are not the same as agro-ecological zones, There are only 3, maximum 4 agro-ecological zones which can be defined based on factors such as climate, soil composition and vegetation. This is also discussed in the AO report

In the 2060s, the mean temperature is expected to increase by +1.2° C on average based on SSP2.45 while SSP5.85 indicates the increase of +1.6° C. The individual models indicate the range from +0.9 to +2.2 ° C for both scenarios during this period. The mean temperature may further increase by +1.9 and +2.7 ° C for SSP2.45 and SSP5.85 respectively during the 2080s. However, the individual models show the increase range between +1.1 and +2.9 ° C for SSP2.45 and +1.9 to +3.2 ° C for SSP5.85 during this period.

The Paris Agreement states the need to control the global mean temperature increase to be within +2 degrees Celsius or preferably +1.5 degrees Celsius with reference to the pre-industrial era. These two scenarios indicate the possibility of the mean temperature increasing beyond +1.5 ° C during the 2060s between 11.1% considering the SSP2.45 and 55.6% for SSP5.85. The possibility extends to 77.8% and 100% for both scenarios during the 2080s respectively. While the possibility of the temperature increasing beyond +2 ° C is about 11.1% during 2060s for both scenarios but increases to 44.4% considering the SSP2.45 and 77.8% for SSP5.85.

These predictions indicate that temperatures in Malawi have been rising and are projected to rise still further. Finer detail in the DCCMS research (2023) reveals that the mean minimum temperatures are rising faster than the mean maximum temperatures thereby reducing the diurnal range, and winter month temperatures are increasing faster than summer months. Research by Zhou et al (2007) suggests that this decrease in diurnal range (the example given in that paper was in the Sahel) can be directly related to decreases in vegetation cover and reduced soil moisture.[23] As vegetation is cleared, the land is more exposed to heating during the day, particularly whilst the sun is shining. During this time, the moisture in the soil diminishes through evapotranspiration and the soil retains heat for longer with reduced outgoing long wave radiation (emissivity) therefore the air above the ground cools less during the night.

This reduction in diurnal temperature range (DTR) has differential implications for the social ecological system (SES). As temperatures increase overall, any reduction in minimum temperatures and diurnal range may catalyse the heating process which has detrimental implications for the diversity and functionality of the SES. However, research in China has also shown that widening DTRs may result in worsening occurrence of stroke and mortality generally, particularly among middle to older age groups (Zhang et al 2017 and Lei et al 2020).[24]

23 https://www.pnas.org/doi/epdf/10.1073/pnas.0700290104

24 Zhang, Y. et al (2017) 'Diurnal Temperature Range in Relation to Daily Mortality and Years of Life Lost in Wuhan, China,' International Journal of Environmental Research and Public Health, 14 (8). Lei, L., et al (2020) 'Effects of diurnal temperature range on first-ever strokes in different seasons: a time-series study in Shenzhen, China,' *BMJ Open*, 10 (11).

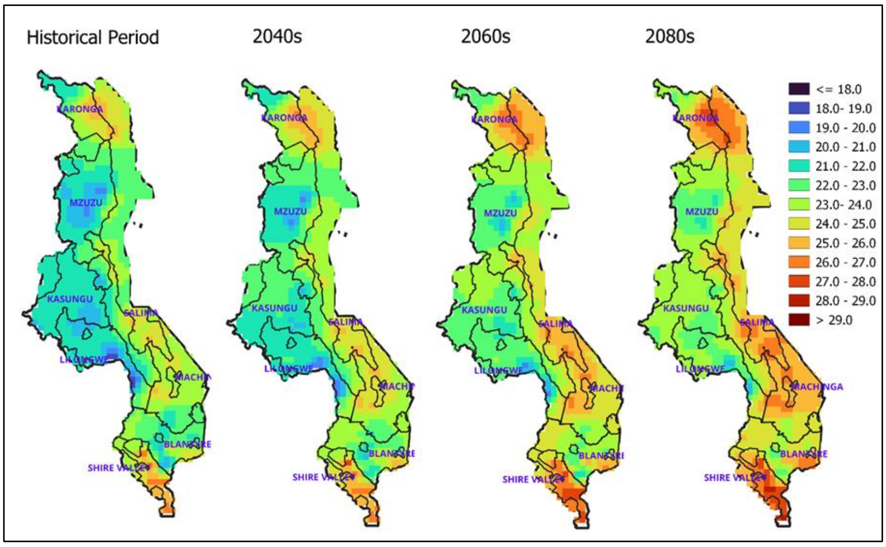

Figure 7. Mapped projected mean temperature change for Malawi in the 2040s, 2060s and 2080s, using SSP2.45 (lower to middle expectations) (DCCMS 2023)

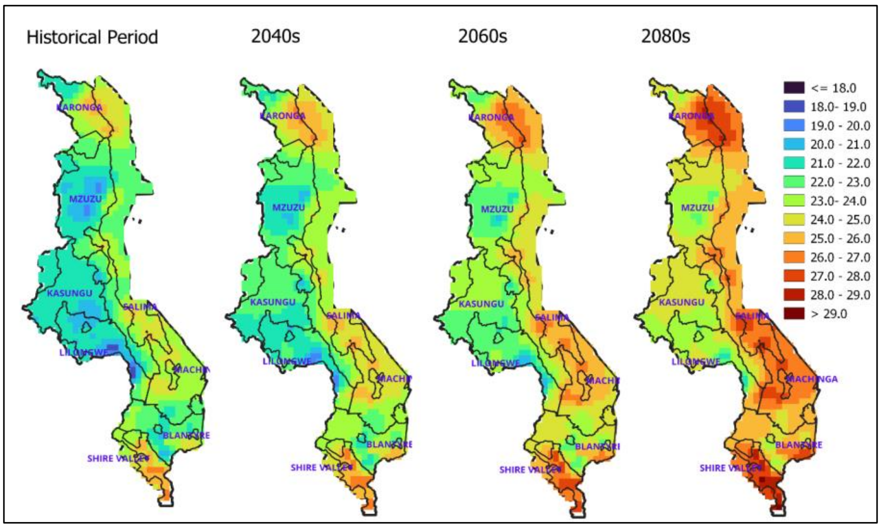

Figure 8. Mapped projected mean temperature change for Malawi in the 2040s, 2060s and 2080s, using SSP5.85 (high expectations) (DCCMS 2023)

Table 3. The maximum temperature changes in 2040s, 2060s and 2080s with reference from 1991-2020 (2020s). The range is the change range for the individual models. The area proportion that has a mean maximum temperature greater than 30.5 degrees Celsius is also presented (DCCMS 2023).

Maximum Temperature Change (oC)						
Period	Mean		Proportion Area >30.5 deg (%)			
Historical (2020s)	28		15.4			
	SSP2.45			SSP5.85		
	Mean change			Mean change		
	Mean	Range	Proportion Area >30.5 deg (%)	Mean	Range	Proportion Area >30.5 deg (%)
2040s	0.3	0.03-0.4	20	0.67	0.4-1.1	24.6
2060s	1.3	0.8-2.3	27.7	1.6	0.9-2.3	33.9
2080s	1.9	1.2-3.1	38.5	2.8	1.4-4.0	53.9

3: Climate Hazard Risk Assessment

In the following risk summaries, first by hazard and secondly by sector, we assume the likelihood of climate change according to the scenarios mapped out by DCCMS (2023) which are grounded mostly on climate and weather evolution during the control period, 1991 to 2020. However, this CRA is taking place at a time when many scientists are talking of a set of climate tipping points being reached beyond which, irreversible change takes place with indicators of a different scale to what went before (see Vignette 3).

Vignette 3: Climate tipping points

The IPCC defines a climate tipping point as a "critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly."[25] Thus, in such a scenario, one climate regime suddenly evolves into another. Quite where these tipping points lie is hard to gauge, nobody really knows but it would almost certainly occur, for example, if the Atlantic conveyor belt stopped or got reversed and/or if the Greenland ice sheet runs dry. But the possible evidence to support such a theory already exists with the occurrence of weather events across the globe where local people repeat the refrain, 'We have never experienced anything like this before.' In November 2023, reports suggest that 'Recent drying over the Amazon could be the "first warning signal" that the rainforest is approaching a tipping point.' Linking deforestation with a rapid reduction in rainfall and delaying the start of the South American monsoon.[26] In Malawi, we heard this refrain with Cyclone Freddy in March 2023, a storm system that was the longest ever recorded, travelling from the waters off the north coast of Australia across the Indian Ocean all the way to South East Africa. Freddy ventured inland, on the back of south-easterly winds, not once, but twice and depositing unheard of volumes of precipitation where it ran out of momentum, over Southern Malawi, such that people said that they knew a heavy storm was coming, they had been warned by DCCMS and they had seen many before, but nothing prepared them for what actually arrived. Similarly, in October 2023, we have seen temperatures 20^{o} C above normal in some areas and in others, the maximum temperature ever recorded being exceeded by 6^{o} C. We might imagine these events to be blips but they are becoming too frequent and intense to be just chance – one-off events. So, how do we prepare a NAP with this in mind? Perhaps the answer is to assume the risk presented in this climate risk analysis but then to leave a margin of error to accommodate changes far in excess of what was previously envisaged or perhaps to build in a degree of flexibility in adaptation planning so that resources are put aside to enhance the scale of adaptation should the need occur. The former would seem prudent in a world where LDC macro-economic finances are pushed into extremes of exigency whenever the global economy receives a negative shock such as occurred with the Covid pandemic.

25 https://climatetippingpoints.info/2021/10/31/ipcc-ar6-climate-tipping-points-feedbacks/
26 https://www.carbonbrief.org/drying-of-amazon-could-be-early-warning-of-tipping-point-for-the-rainforest/#:~:text=Over%20the%20past%2040%20years,critical%20threshold%2C%20the%20authors%20say.

a. Rainfall, storms

From the DCCMS climate analysis and projections carried out for this CRA, on considering the rainfall scenarios for the three projection periods, there is no clear agreement in the models on how rainfall patterns are likely to change. Overall totals are likely to decline slightly in some districts though not all, and the number of days with **extreme rainfall events are projected to increase**, particularly in the Southern Region and most especially in the Lower Shire Valley (including Chikwawa District) though by how much is not clear as the annual totals decline and increase again across the projection periods in RCP2-4.5 and increase then decline again in RCP5-8.5 (see Figures 9, 10, 11, 12 and 13 below). Uncertainty is increased by the evolving ENSO phases with deepening El Nino/IOD activity set to bring more rainfall to the northern region and more drought to Southern Malawi and La Nina phases including the prolongation of La Nina, bringing more storm activity to the Southern Region and more drought activity to the Northern Region. For Central Region, including Dedza, Salima and Kasungu districts, there is likely to be more convergence with the Southern Region than the Northern due to the intervening highland massif of the Nyika plateau which tends to act as an orographic barrier to northern and southern climate influences although both may extend along the coastal strip and over Lake Malawi. In all regions, the dry season (May to October) is likely to get drier and that may result in the disappearance of the fine mizzle with cloudy skies condition that sometimes occurs called the "Chiperoni Rains."

Commenté [LP7]: Could you please bold the main finding of each paragraph to ease reading?

Commenté [LF8R7]: Done

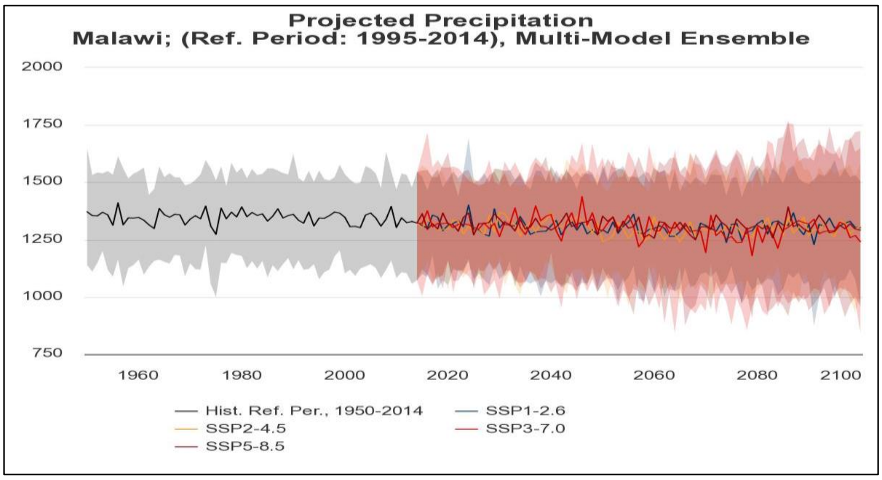

Figure 9.Mean annual rainfall (observed from 1950 to 2016, shaded grey (control period 1991-2014) and projected from 2017 to the end of the twenty-first century. As can be seen, no major change during the projected periods can be discerned but the level of uncertainty created by the multi-model ensemble is high and gets higher as the century draws to a close. (World Bank Climate Knowledge Portal 2021).27

Being in a climate transition zone, the influence of one or the other sets of climate drivers can cause rainfall distribution and type to fluctuate. Warnatzsch and Reay (2019) observe that between 1961 and 2005, the country has seen a slight decrease in precipitation levels every decade, from an average of 1140.8 mm in 1961–1970 to 1042.4 mm in 1991–2000. Meanwhile, annual precipitation varies greatly

27 https://climateknowledgeportal.worldbank.org/country/malawi/climate-data-projections

from year to year (with a standard deviation of 110.9).28 In 1989, for example, average precipitation across the country amounted to 1317.8 mm while, the next year, an average of only 939.1 mm was received, a drop of almost a third.29 Inter-annual precipitation variability in Malawi is high and is projected to increase and this can make it difficult to identify long term trends. But this is an increasing global tendency as global climate models project that interannual precipitation variability will increase with rising greenhouse gas concentrations.30 I**n summary, projections of rainfall over Malawi do not show statistically significant changes in trends.**

Commenté [J[9]: trends or changes in trends?

Commenté [LF10R9]: Changes in trends can serve well here. Text changed.

28 Warnatzsch, E.A. and Reay, D.S. (2019) 'Temperature and precipitation change in Malawi: Evaluation of CORDEX-Africa climate simulations for climate change impact assessments and adaptation planning,' *Science of the Total Environment* 654 378–392

29 Ibid

30 Harp, R.D, and Horton, D.E. (2023) 'Observed Changes in Interannual Precipitation Variability in the United States,' *Geophysical Research Letters,* 50, 13.

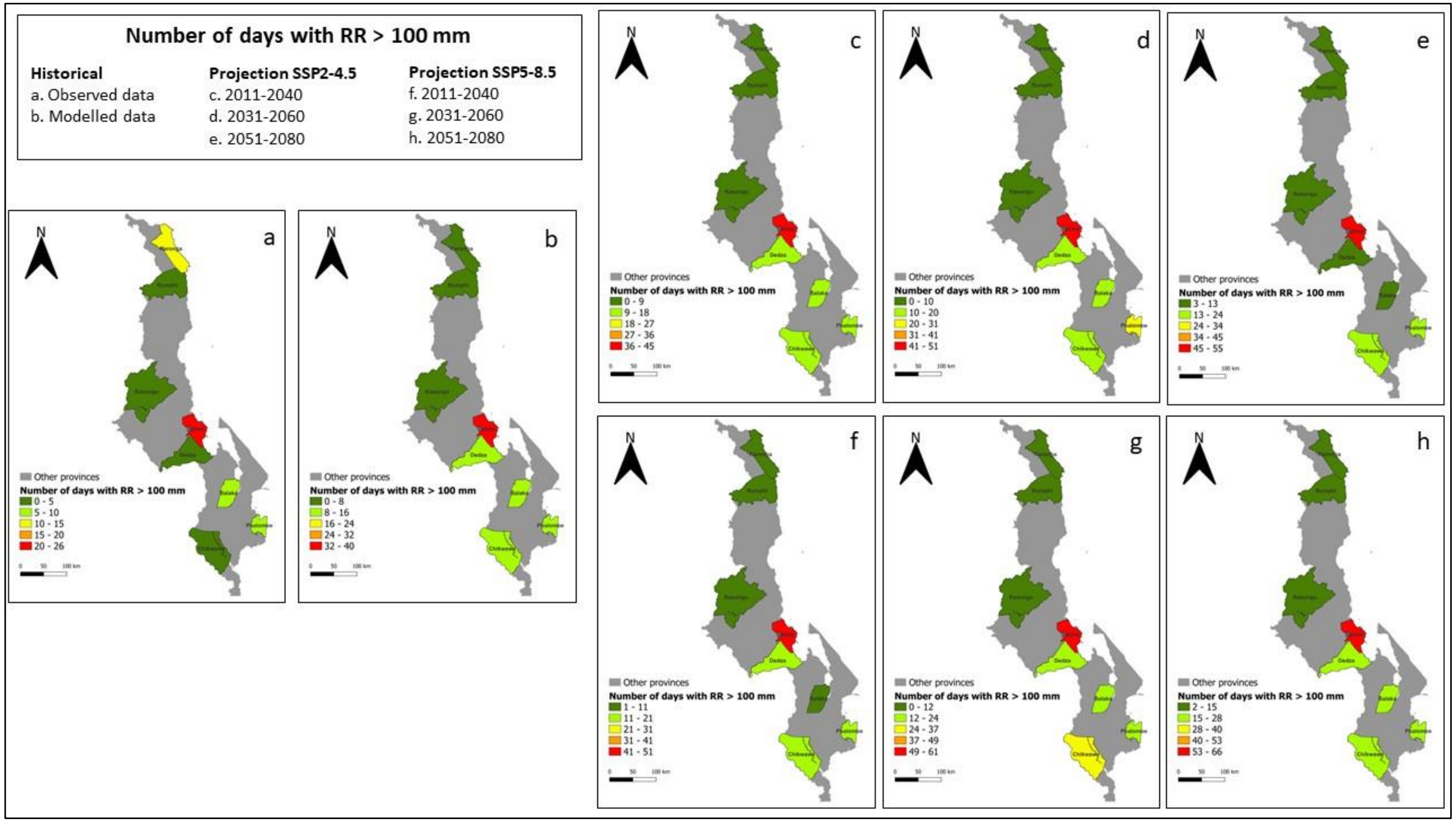

Figure 10. Number of days with RR >100 mm

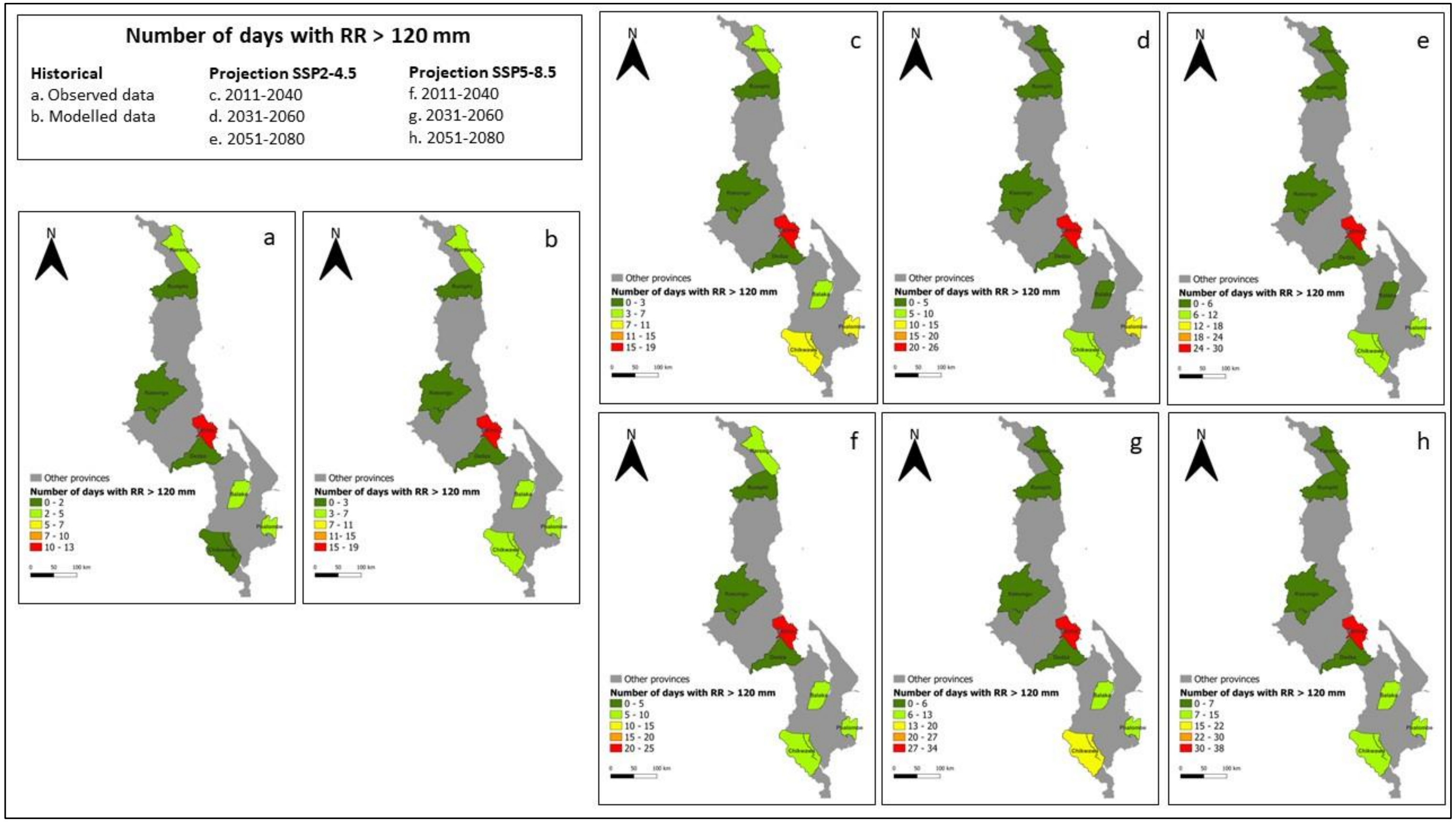

Figure 11. Number of days with RR >120 mm

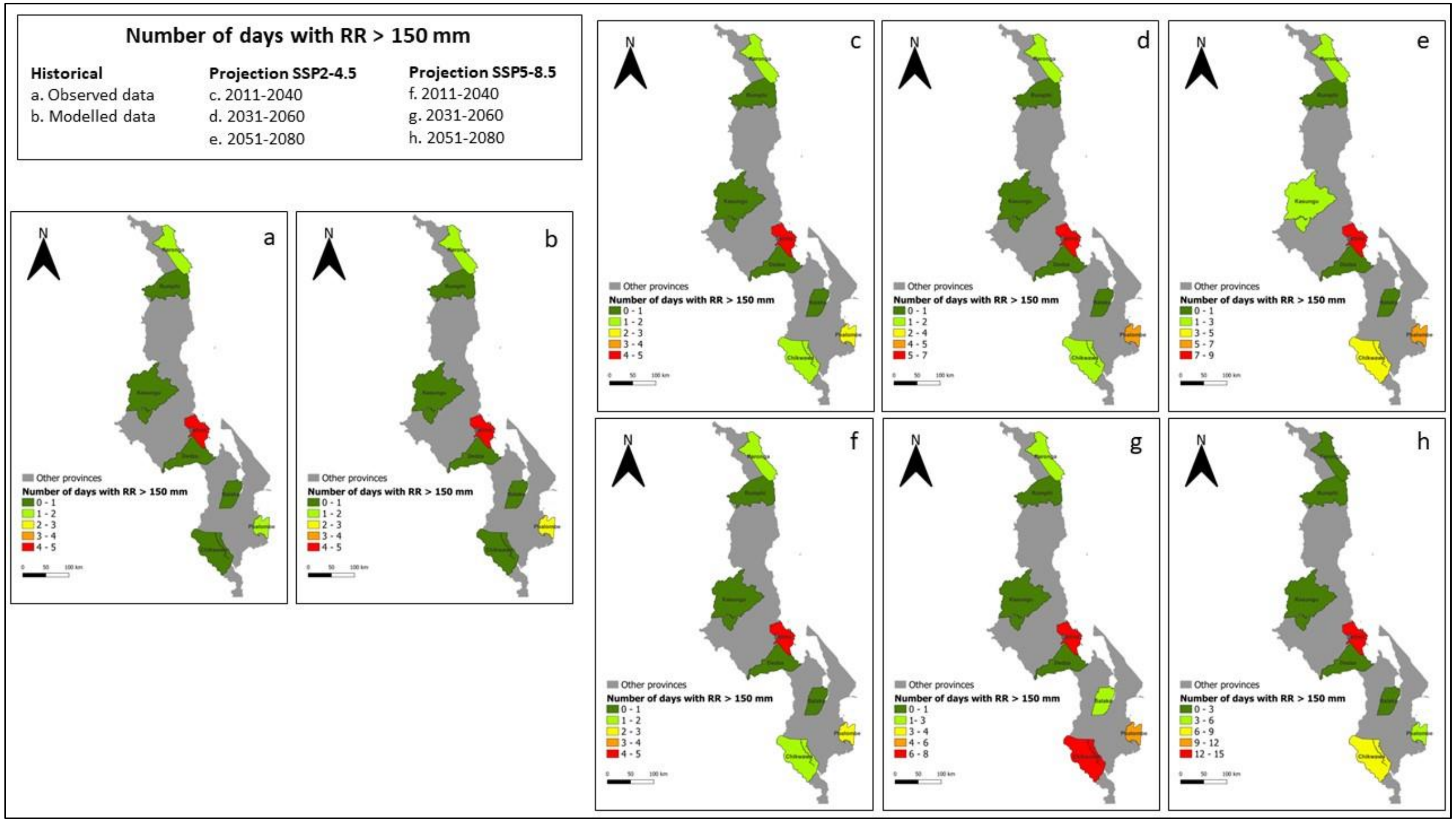

Figure 12. Number of days with RR >150 mm

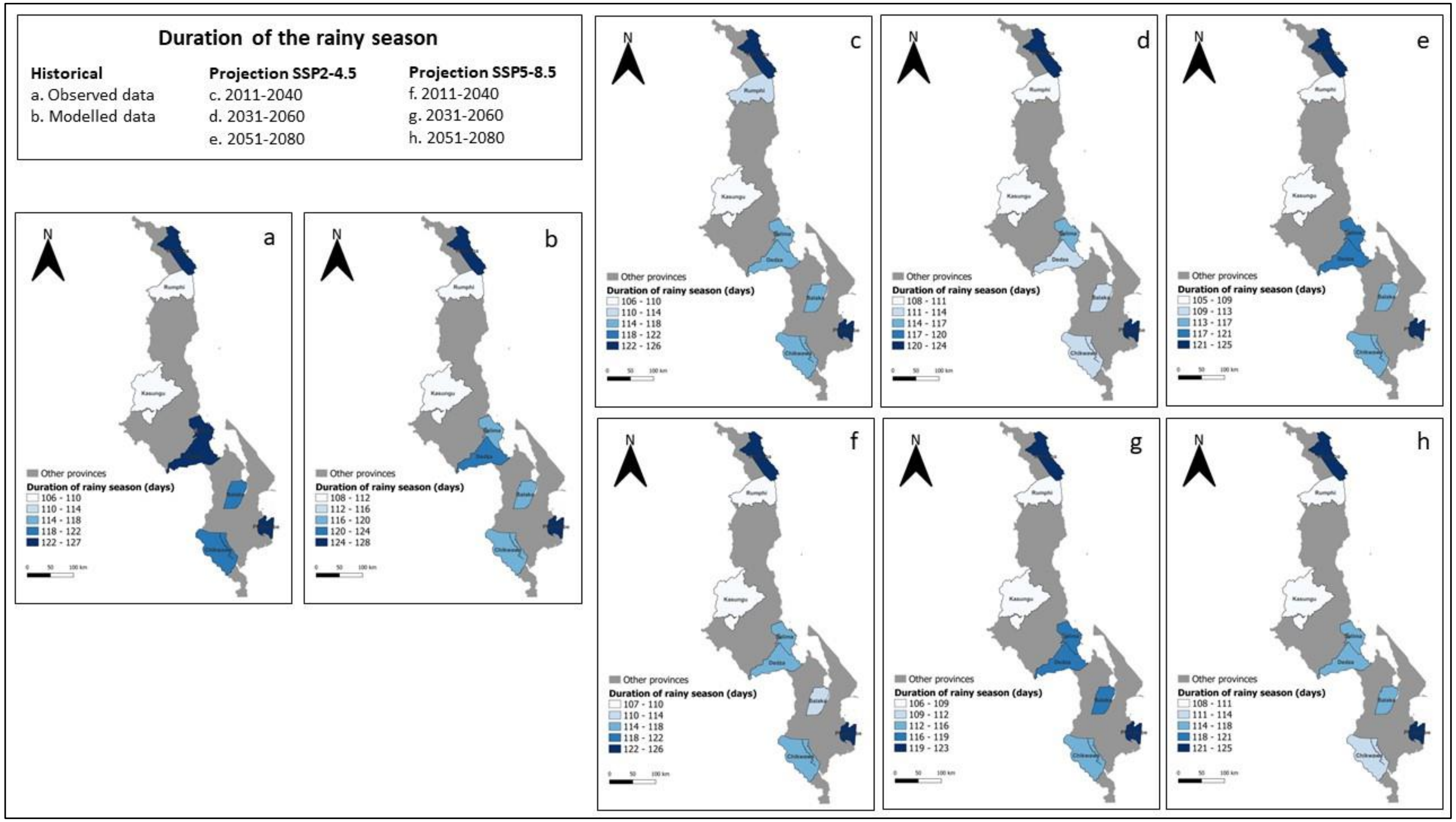

Figure 13. Duration of the rainy season

Figure 13 above shows the evolution of the projected length of the growing season for the 8 focus districts compiled from data supplied by weather stations in each ADD. These have been compared with secondary research by Kazembe (2014),31 Ngongondo et al (2014),32 Nicholson (2014),33, with the observation that there is little coherence between the models.

To get a better picture, evidence from more locations in the district stations is necessary, which requires more weather station infrastructure . What can be said is that the growing season is shortest in the Lower Shire River Basin (including Chikwawa District) and in the west of Central Region (including Kasungu District) and highest in the Northern Region (including Karonga District). **Dates of onset and closure and length of growing season for the projected time periods show little variation with slight increases in length of growing season from 2020-2040 to 2040-2060 and regression again between 2040-2060 and 2060-2080**. Kazembe (2014) also shows that the standard deviation in the compilation of onset, closure and length of growing season is highest in the South which correlates with inter-annual variability and the increasing likelihood of extreme weather events, both rapid and slow onset, in that region.

There have also been perceived changes in local wind patterns. During the Field Mission workshop series undertaken for this CRA, all eight focus districts reported more intense winds, most notably when discussing weather on or from Lake Malawi and seven out of eight districts reported an apparent change in direction of winds. Furthermore, a number of informants interviewed both during the workshops and the field visits highlighted changes in wind patterns as one of the most visible impacts of climate change in Malawi. This evidence is supported in the literature by fishers on Lake Malawi, "fishers reported increased incidences of … persistent Mwera winds (strong South easterly winds affecting Lake Malawi due to the flat and obstruction-free nature of its surface, allowing winds of considerable strength to develop. The onset of a Mwera can be quite sudden, causing rapid deterioration in the condition of the lake itself) (11%) and flooding (8%)."[34] The ways winds originate over Lake Malawi is discussed in Koseki and Mooney (2019),[35] while one possible explanation for the observations of fishers, particularly commenting on wind patterns over the last few years is that during wet years (such as when La Nina phases is in the ascendency over the Indian Ocean, there comes about a convergence of strong north-easterly and south-easterly winds over the lake that do not occur during dry periods.[36]

Commenté [J[11]: This is very interesting - are there relevant scientific studies which might corroborate this information from informants and workshop participants?

Commenté [LF12R11]: There is a paucity of biophysical science studies on wind pattern changes over Malawi but I have located some corroborating evidence from fishers and a reference for a possible scientific explanation for what is being reported. See new text and extra references. Unfortunately, we were unable to elicit further support to investigate further thru DCCMS

Storms with lightning, heavy rainfall and storm force winds lead to loss and damage to both the natural and built environments. Heavy rain can cause knocking-over and washing away of crops, death to livestock and overwhelming of drainage. Structures that are weak can be destroyed and damaged. The scale of this, given the frequency and increasing back-to-back nature of extreme events suggests that there is an increasingly high risk of loss and damage from storms, and both pluvial and fluvial flooding in Malawi, partly because of low resilience in the form of low reception and understanding

31 Kazembe, C. (2014) 'Determining the onset and closure of seasonal rains in Malawi,' Unpublished Post-Graduate Diploma thesis, Department of Meteorology, University of Nairobi
32 Ngongondo, C. eta l (2014) 'Growing season length and rainfall extremes analysis in Malawi,' *'Hydrology in a Changing World: Environmental and Human Dimensions,'* Proceedings of FRIEND-Water 2014.
33 Nicholson, S. et al (2014) 'A detailed rainfall climatology for Malawi,' *International Journal of Climatology,* 34, 2.
34 Limuwa, M.M. et al (2018) 'Evaluation of Small-Scale Fishers' Perceptions on Climate Change and their Coping Strategies: Insights from Lake Malawi,' *Climate*, *6*, 34.
35 Koseki, S. and Mooney, P.A. (2019) 'Influences of Lake Malawi on the spatial and diurnal variability of local precipitation,' Hydrology and Earth System Sciences, 23, 7, 2795–2812.
36 Libanda, B. et al (2017) 'Variability of Extreme Wet Events over Malawi,' *Geographica Pannonica*, 21, 3, 212-224

warnings/forecasts and, therefore, in preparedness. One may also consider inadequate infrastructure, inappropriate farming methods, problems in institutional capacity, including adaptive capacity and economic poverty. Water that spills out of drains and into channels may also carry pollutants and embody erosion hazards that have implications for rural and urban ecosystems downstream. In the case of Malawi, we have observed problems caused by siltation in floodplains and stream outlets by ongoing high soil erosion throughout the country and pollution of rivers, lakes and livelihood activities such as fishponds, loss and damage to the built environment and to social sectors such as health and education which become disrupted, and to vital infrastructure such as communications networks, power and water infrastructure.

b. Flooding

The Flood Risk Assessment (national and 3 sub-catchments) is presented in the accompanying document 'Flood Assessment in Malawi'. Flooding has been identified as the hazard that causes most damage to the SES in Malawi. Possibly, this is because it is a rapid-onset event where the ramifications are immediately visible and easy to be visualised whereas damage from a slow onset event like drought or desertification does not present such stark processes of change although it can be just as impactful. Flooding is the most common disaster in Malawi, accounting for around 40% of all recorded disasters,37 costing around 1.7% of GDP.[38] Between 1946 and 2013, floods accounted for 48% of disasters in Malawi and their frequency and severity is increasing.[39] Floods have affected 17 of Malawi's 28 districts with Chikwawa and Nsanje in the Lower Shire Valley being the worst affected.[40] Floods stifle development efforts at every level and affect many sectors from agriculture to health/sanitation, infrastructure, environment and education. Whilst floods are a direct result of climate and extreme weather patterns, the impacts of disasters, like floods, are a consequence of social and economic factors. For example, high poverty levels mean people lack access to land and work and they are often driven to settle in zones that are more exposed to natural hazards. Also, extensive deforestation increases runoff and the overall flood risk.

A number of challenges exist in addressing flooding, which has been part of natural ecosystem evolution in the sub-region. Arguably, these challenges have not changed since the colonial era when they were first identified. There's not enough funding, community participation is limited, while the existing decentralised governance system isn't sufficiently empowered to be an effective interlocutor in mitigation of impacts or in adaptation. Thus, project planning, implementation and maintenance isn't smooth. One explanation may be related to limited involvement of local communities in planning and decision-making, as suggested by district respondents during participative risk assessment for this work which implies that local knowledge of climate signals and historical coping and management strategies may be overlooked. In such cases, flood improvement projects may lack ownership by the

37 Dewa, O. et al (2021) 'Assessing Capacity and Implementation Status of the Disaster Risk Management Strategy for Health and Community Disaster Resilience in Malawi,' *International Journal Disaster Risk Science*, 12, 673–688.
38 Government of Malawi (2019) 'Malawi 2019 floods post disaster needs assessment,' Lilongwe: Government of Malawi.
39 Ibid
40 https://floodlist.com/africa/malawi-floods-17-districts-affected#:~:text=So%20far%2017%20of%20the,%2C%20Zomba%2C%20Chikwawa%20and%20Nsanje.

community which undermines any gains in DRR/DRM as was voiced many times during the field research for this report. Without that ownership, the risk is high that DRR/DRM initiatives will either fail or enjoy only limited and ephemeral success.

By whatever measure is deployed, Malawi usually ranks as one of the poorest countries in the world.[41] More than 71% of Malawians are living below the poverty line, of whom, an estimated 20% are living in extreme poverty.42 This poverty has a direct bearing on the behaviour and actions of communities that may exacerbate the impacts of flooding. As has been noted above, over 80% of Malawians rely on agriculture for a living. Most are smallholder farmers. With their livelihoods reliant on a single rain-fed season they are particularly vulnerable to floods. Recent research shows that smallholder farmers lose 2.67% of their agricultural produce to flooding each year.[43] High levels of poverty, a lack of access to land and a growing population means people have smaller pieces of land for farming. This has led to settlements and cultivation in marginalised areas that are prone to flooding. Another factor contributing to people's vulnerability is that housing and infrastructure are of poor-quality construction and durability. In addition, there's a lack of economic diversification, employment opportunities (for example in piecework when crop failure on smallholdings occur) and access to virtually any form of social services. This means that people are limited in how they can prepare for a possible flood and bounce back after it's happened.

Flood events are projected to increase in frequency and volume in the future throughout Malawi but especially in the south, together with accompanying loss and damage, especially if flood risk management (FRM) systems are not improved. Early warning has, to date, not been very effective in preventing catastrophe. In the south of Malawi in particular, the communication ahead of floods like Tropical Cyclone Idai in 2019, failed to enable flood disaster management to prevent property damage, displacement and deaths with only scientific flood forecasting systems (SFFS) deployed.[44] Hussein (2023), who studied areas in Chikwawa District, highlights the failure of the SFFS to sufficiently warn communities ahead of the flooding caused by Cyclone Idai, while identifying the existence of a flood forecasting system fuelled by indigenous knowledge (IFFS – indigenous (knowledge) flood forecasting system), which, in itself, is deficient in forecasting the scale and precise timing of impending floods. Hussein advocates the idea of integrating the two systems.[45] Hussein's advocation is reinforced by an earlier study by Trogrlić (2019) that looked at communities in both Chikwawa and Nsanje Districts, saying that stakeholders involved with flood risk assessment and local level flood risk management (FRM) often overlook, undervalue and underutilise local knowledge strategies stating that, '…local communities have a complex knowledge system that cuts across different stages of the FRM cycle and

Commenté [LP13]: Is that part of the CRA? What is the source?

Commenté [LF14R13]: I have edited the text in this para to be less absolutist. The evidence of these assertions were provided at the meeting with Chikwawa District Council in October 2022 and at different workshops during our field mission. The same view is presented in other papers but it would take me long to re-research where these inferences are made. I will try to revisit some of these. In the meantime, if you prefer that this text is excluded, please advise

Commenté [J[15]: Might be a slight exaggeration, for example Malawi is 169 out of 191 on human development: https://hdr.undp.org/data-center/country-insights#/ranks

Commenté [LF16R15]: I guess it depends on what index or measure you use but I agree it is better to remove a numerical figure of exactly how far down the poverty league table Malawi comes. Text changed and 2 references added.

Commenté [LP17]: Repetition from above

Commenté [LF18R17]: OK

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[41] https://www.worldbank.org/en/country/malawi/overview and https://actiononpoverty.org/our-impact/where-we-work/malawi/#:~:text=Malawi%20is%20one%20of%20the,Malawians%2C%20especially%20in%20rural%20areas.

[42] https://www.concern.org.uk/where-we-work/malawi?gclid=Cj0KCQjwhfipBhCqARIsAH9msbkR2pjIWCKNXL5VmE1mcxsOpqQC-OBHQU8nQYlzJo-zCjwi6b4kf6AaAld8EALw_wcB

[43] https://www.preventionweb.net/news/why-malawi-failing-protect-people-floods-and-what-needs-be-done

[44] Hussein, D.N. et al (2023) 'Flood Forecasting in Malawi's Shire River Basin,' *American Journal of Environmental Sciences,* 19, 2, 43-53.found online at https://www.researchgate.net/publication/371142515_Flood_Forecasting_in_Malawi's_Shire_River_Basin

[45] Ibid

forms a component of community resilience.'[46] In Malawi to date, the scale of loss and damage resulting from flooding, which appears to be comparatively high for the sub-region, is such that scientific forecasting alone, may be insufficient.

To summarise, patterns of future rainfall, as in the past, are highly uncertain. Out of 34 models in one survey, almost half show that changes in mean annual rainfall are likely to be less than 5%, whilst the rest disagree on whether it will be wetter or drier.[47] This means we have lower confidence in projections of future rainfall changes. With this level of uncertainty, the risk element is that while we know that there will be increasing demand for water from expanding populations, agricultural needs and urban areas there may be less water available for lives and livelihoods and for uses like power generation due to increasing climate variability. What can be said with certainty is that recent evidence, provided here, indicates that unprecedented occurrence of storms and heavy rainfall are becoming more the norm, especially in the south of the country. If there are to be more heavy storms and the annual rainfall is projected to remain fairly constant, this would indicate more dry periods in between storms and therefore, because the water budget will be less consistent, indicates the probability of a drying a drying climate, especially when higher temperatures and consequent higher evaporation are taken into consideration (see below under evapotranspiration). Due to the inter-modular variation described, adaptation planning needs to take a range of possible rainfall scenarios into account as rainfall is directly related to water security.

c. Temperature and dryness hazards

i. Temperature

There is more model agreement on temperature. A clear warming trend is apparent in mean annual temperature and, in contrast to rainfall, there is strong agreement on continued future warming throughout Malawi. Warming is in the range of 0.5 to 1.5°C by the 2040s, evenly distributed across the country. By the 2090s, warming is projected to be in the range of 2.3 to 6.3°C, also evenly distributed across the country.[48] There is also strong coherence that the occurrence of extreme heat will increase, in all areas but most especially in the south. This increase in temperature has been most rapid in the early summer dry season (September to November). Mean temperature increase is accompanied by higher frequency of extreme temperatures (in excess of 35° C) (see Figures 15, 16, 17, 18, 19 and 20). These trends also contribute to the drying identified in rainfall above.

The charts in Figure 14, adapted from CDKN (2017) display how warming is predicted to occur.[49] In chart a) we see the control period 1976-2005 with observed temperatures showing how the hottest temperatures occur in the far south and over Lake Malawi while in the near (2021-2050) and far (2070-2099) term periods (Charts b and c), the projected increases in degrees C are mapped. In these it can confirmed that the biggest increases in temperature will be in the September to November period – already the hottest time of year with the Central and Southern Regions receiving the most increase.

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[46] Trogrlić, R.S. et al (2019), 'Characterising Local Knowledge across the Flood Risk Management Cycle: A Case Study of Southern Malawi,' *Sustainability*, 11.

[47] https://www.futureclimateafrica.org/wp-content/uploads/2017/10/2772_malawi_climatebrief_v6.pdf

[48] CDKN (2017) Future Climate for Africa - Country Climate Brief: Annex: Future Climate Projections for Malawi.' found online at https://www.futureclimateafrica.org/wp-content/uploads/2017/10/2772_malawi_climatebrief_v6.pdf

[49] Ibid

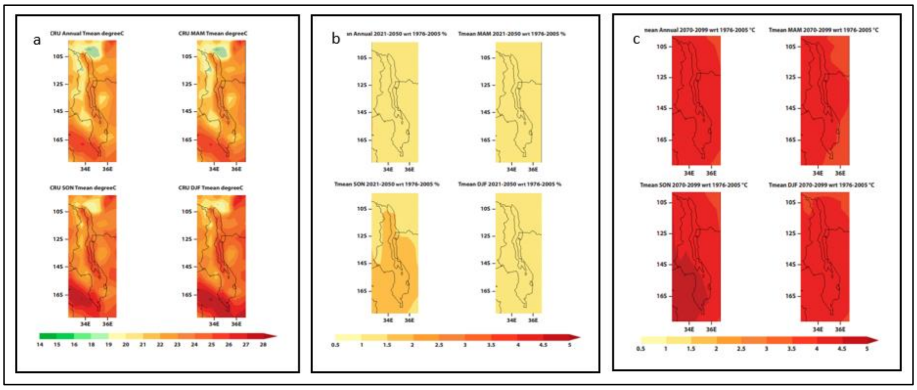

Figure 14. a) Observed annual and seasonal mean temperature (°C) for 1976-2005. Seasons are March to May (MAM), September to November (SON) and December to February (DJF); b) Mean seasonal temperature change (°C) for near-term 2021-2050 compared to current period

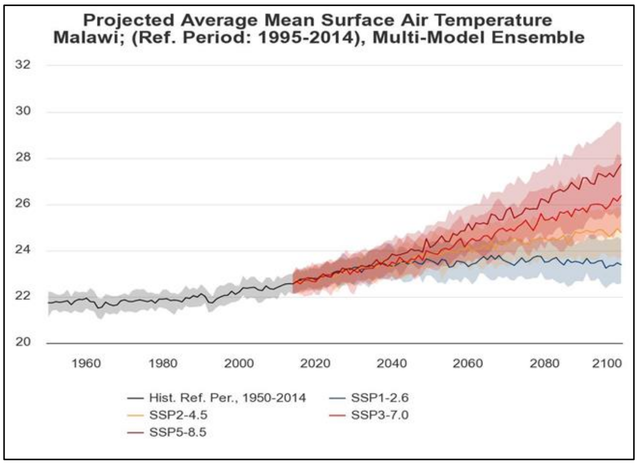

Figure 15. Average temperatures for Malawi 1950-2014 (shaded in grey) and projected 2014-2100. Note the increase in uncertainty as the models diverge from the middle of the 21st century (World Bank, 2021).

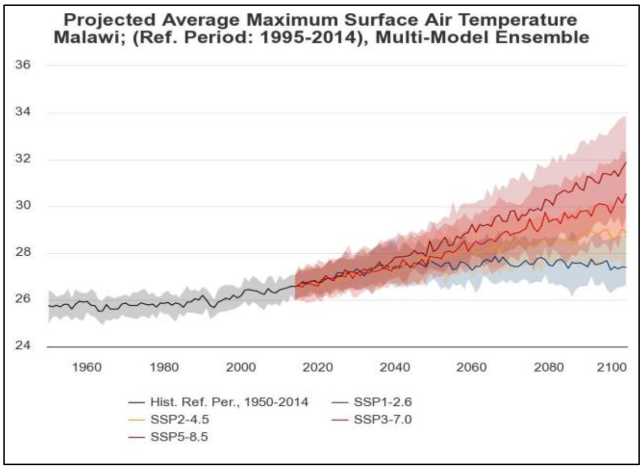

Figure 14~~16~~. Graph showing projected change in mean maximum temperatures for all Malawi with observed from 1950-2014, shaded in grey, and using 1995-2014 as control period (World Bank, 2021).

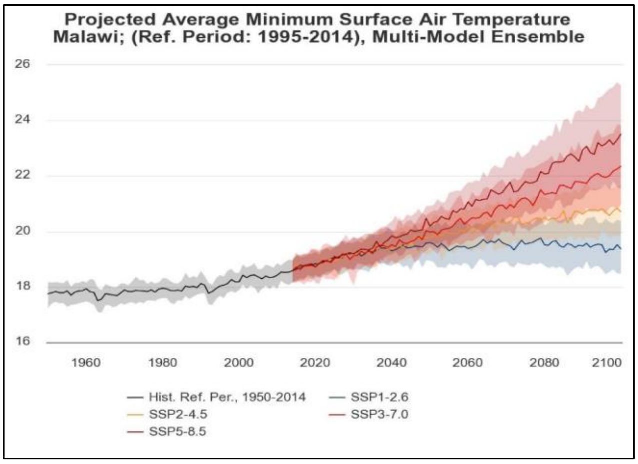

Figure 17. Graph showing projected change in mean minimum temperatures for all Malawi with observed from 1950-2014 and using 1995-2014 as control period. Note that increases in minimum temperatures are greater than increases in maximum temperatures thereby narrowing the diurnal range.

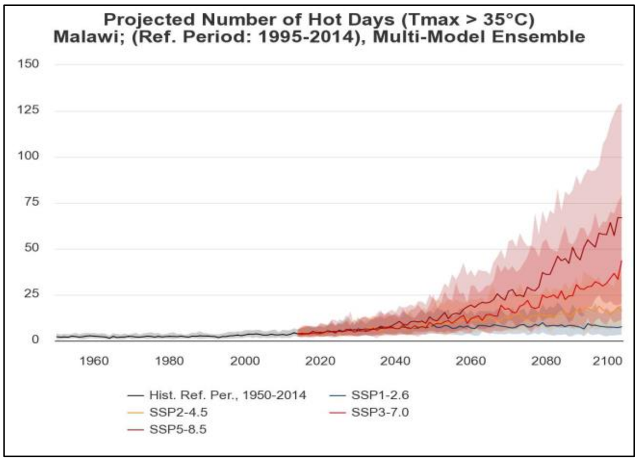

Figure 18. Observed number of hot days over 35 degrees C 1950-2014 (shaded in grey) and projected 2014-2100. Note the increase in uncertainty as the models diverge from the middle of the 21st century and the acceleration of projected occurrence (World Bank, 2021)

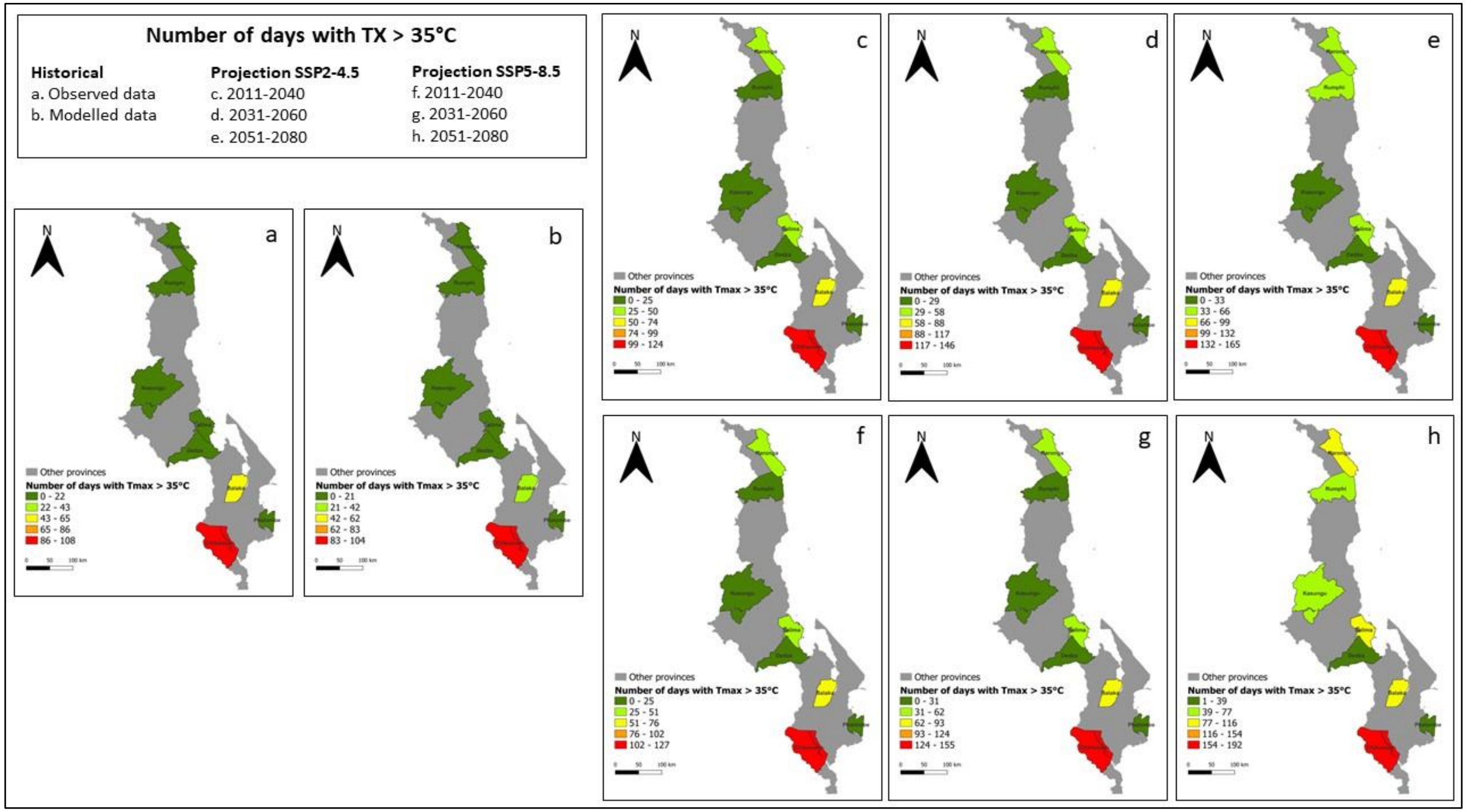

Figure 19. Number of hot days exceeding 35 degrees C by district*

*Historical to the left; then, projected by SSP 2-45 on the upper echelon and SSP 5-85 on the lower echelon. Note the preponderance to hot days in the South. The measures for each colour code differ from projection to projection.

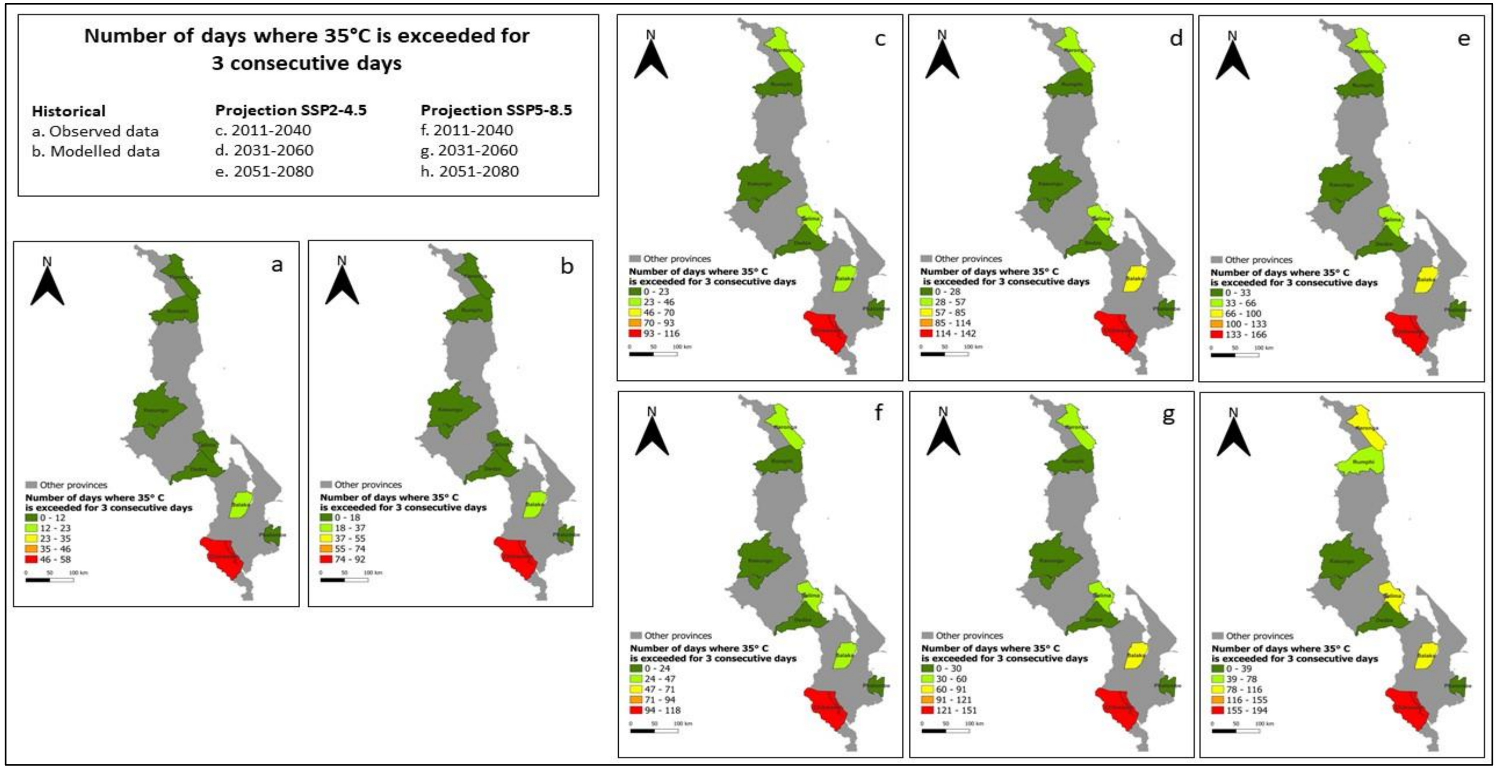

Figure 2015. Number of days where 35 degrees C is exceeded for 3 days at a time by district (in total days) *

*Arranged as in Figure 20.

This kind of rapid warming being experienced now and predicted for sub-tropical zones may well result in climate tipping points being breached with hitherto unknown weather extremes occurring. It can also have repercussions for the natural environment. The range of flora and fauna species may start to change as some species die out and others start to thrive. Those species that are vulnerable to evapotranspiration and large-leaved varieties are most at risk while succulents and small leaved species such as acacia, are likely to thrive. Overall, the hotter it gets, the less biodiversity there is likely to be. Certainly, there are risks to many fish species as surface layer temperatures in the lakes and rivers increase. A further risk is to vegetation and the insects which pollenate with increasing temperatures and heat extremes, desiccation will set in very easily and many species will not be able to survive.[50]

Commenté [LP19]: Please add references

Commenté [LF20R19]: Done

Higher temperatures also result in higher evaporation of both surface water bodies and soils affecting water for lives and livelihoods. Higher temperatures and temperature extremes are very likely to have negative impacts on health. Heatwaves lead to an increase in heatstroke and heat-related illnesses, with vulnerable groups such as the elderly, infirm and the very young being particularly affected. Additionally, food and water scarcity resulting from climate extremes worsens malnutrition, further impacting health outcomes. These climate-related events have detrimental effects on the health and well-being of the population which is then reflected in their productivity. Implementing measures to mitigate heat-related illnesses, ensuring food and water security, and promoting nutrition interventions are crucial for protecting the health of the community during climate extremes.

ii. Evaporation and drought

Temperature increases and occurrence of temperature extremes are forecast to be most significant in the months of September, October and November. Unfortunately, we were unable to access data on rates of evaporation/evapotranspiration. However, evaporation is a serious problem for Malawi, not least because of the high proportion of the country covered by water – the 4 lakes plus the river systems that drain the Lake Malawi-Shire River Basins (LMSRB) and also due to the extensive deforestation that has taken place in recent decades, which causes run-off and soil erosion but also prevents the release of water vapour back into the atmosphere, therefore discouraging the formation of rain clouds.[51] When rainfall drops or ceases completely during dry spells, evaporation becomes concentrated in diminishing water levels in lakes and rivers. When combined with increasing hot temperatures, the evaporation from water bodies increases dramatically and, while loamy soils dry and compact, sandy soils turn to dust waiting for the first rains to wash these fine grains away.

Commenté [LP21]: Reference please

Commenté [LF22R21]: Done

Evidence presented in this CRA suggests that rainfall is likely to decrease in the North and Centre of the country more than in the South.52 Concomitantly, temperatures are likely to rise substantially, but most especially in the south.53 One may think that, in the South, the drying trend will be offset by a relatively unchanged rainfall total but this is not the case because rainfall, especially in the south, is

[50] Bita CE, Gerats T. (2013) 'Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat stress-tolerant crops,' Frontiers in Plant Science, 4: 273, Bodlah, M.A. et al (2023) 'Insect behavioral restraint and adaptation strategies under heat stress: An inclusive review,' *Journal of the Saudi Society of Agricultural Sciences,* 22, 6, 327-35

[51] https://www.earthreminder.com/how-does-deforestation-affect-the-water-cycle/

Note: forests release water vapour into the atmosphere via transpiration. As water vapour rises and condenses, it facilitates cloud formation. The interplay between evaporation and condensation in forests has a profound impact on climate, dictating local and regional weather patterns.

[52] CDKN (2017) 'Future climate for Africa-country climate projections for Malawi,' found online at https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/10/2772_Malawi_Annex.pdf

[53] Ibid

likely to consist more of storms and extreme rainfall events which result in extensive run-off and less addition to the water budget through percolation. Meanwhile, it was established in the 1980s, that evaporation over Lake Malawi amounted to around 70% of inputs – from rainfall and outflow from tributary streams.54 Since that time, deforestation has soared and natural vegetation has been cleared for agriculture, burning for charcoal and brick-making and urbanisation. This forestry and other vegetation served to constrain evaporation by feeding water vapour back into the atmosphere and protecting soil-water budgets by virtue of shade and canopy cover. Removal of vegetation cover results in less water at the surface and more evaporation leading to intensification of drought which is shown to have occurred in the period. Mtilatila (2020) demonstrates that a noticeable increase in meteorological droughts occurred in the period 1970-2013 and that, while hydrological drought (when surface water levels become seriously diminished and shortages of water occur) correlates with this occurrence, the latter tended to follow after a time lag (up to 24 months) and would not be so frequent but would be more prolonged. More than one meteorological drought may, cumulatively, lead to a hydrological drought.

In Figure 21, Mtilatila (2022) presents the SPEI (Standard precipitation evaporation index) time series of 16 GCMs and RCMs (general and regional circulation models, respectively) and their ensemble means for the period 1976–2005 (historical period), 2021–2050 (near-term period), and 2071–2100 (far-term period) using bias-corrected datasets.55 The SPEI during the historical period shows high uncertainty and variations among the individual models. As a result, the ensemble mean of the models rarely goes beyond −1 and +1, and it can be seen that the ensemble members only vaguely represent the observed SPEI (RED graph). In the future scenarios, though, the SPEI decreases (which indicates an increase in drought intensity) from the historical period to the near and far-term periods. The wet episodes during the historical period become fewer and fewer in the future, as dry conditions become more prominent. The increase in drought during 2021–2050 is similar for both RCP4.5 (green line) and RCP8.5 (yellow line),56 but the mean intensity of RCP8.5 is more than that of RCP4.5. During 2071–2100, the SPEI based on RCP4.5 stabilizes, while the SPEI based on RCP8.5 constantly keeps on decreasing. It is also noted with many ensemble members that they have one continuous drought episode during the entire period of 2071–2100. The model uncertainty (spread of models) is large, which starts during the historical period and increases over time. The SPEI based on RCP8.5 shows greater uncertainty than that based on RCP4.5, and the mean intensity of the SPEI based on RCP8.5 is noticeably larger than that based on RCP4.5 during this period.

The postulations by Mtilatila (2020 and 2022) emphasise the Importance of considering the SPEI when seeking to identify drought risk in the future in Malawi as projections for changes in rainfall are so uncertain. Whilst we were unable to obtain SPEI data for the exact future periods assigned to this CRA, we can see from Mtilatila's work that while overall rainfall totals may not be projected to change very much in the future, the distribution of rainfall will change to the extent that evapotranspiration will diminish and, therefore, the likelihood of deepening and prolonged droughts is likely to increase. This

[54] Mtilatila, L. et al (2020) 'Meteorological and hydrological drought assessment in Lake Malawi and Shire River basins (1970–2013),' *Hydrological Sciences Journal*, 65:16, 2750-2764

[55] Mtilatila, L. et al (2022) 'Temporal evaluation and projections of meteorological droughts in the Greater Lake Malawi Basin, Southeast Africa,' *Frontiers in Water*, 4.

[56] A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the IPCC. RCP4. 5 is a scenario that represents a stabilisation of greenhouse gas concentrations by 2100 and could be realistic if moderate global action is taken towards mitigating greenhouse gas emissions. RCP 8.5 is the highest baseline emissions scenario in which emissions continue to rise throughout C21.

represents the drought hazard risk together with an implied increase in the likely impacts of drought in terms of water availability and human security.

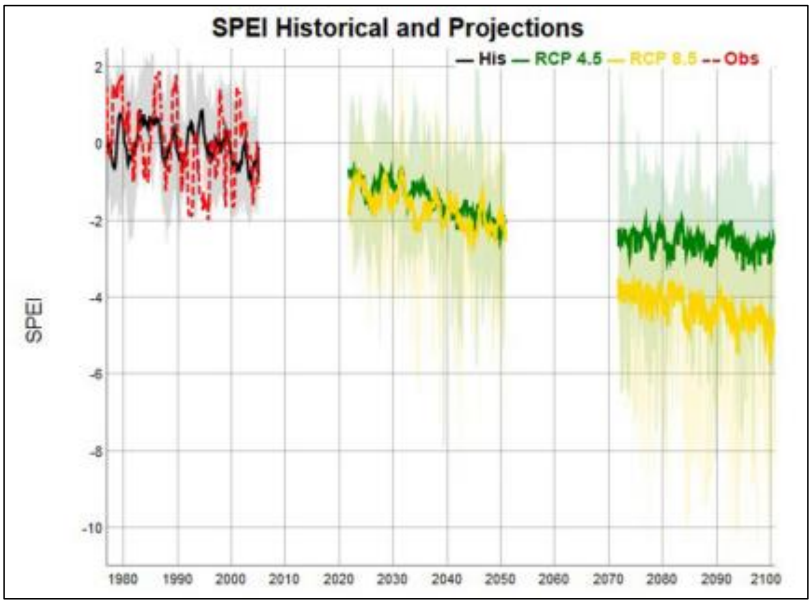

Figure 21. The standardized precipitation and evapotranspiration index (SPEI) series for observations and the 16 bias-corrected GCM–RCM combinations and associated ensemble means for (i) the historical period 1976–2005, grey-ensemble members, black-ensemble mean, and red-observations. (ii) 2021–2050 and 2071–2100 future periods. Green-RCP4.5 and yellow-RCP8.5 (Mtilatila 2022).[57]

d. Consideration of Lake Malawi

Freshwater lakes are a critical natural resource for all aspects of those socio-ecological systems that are found in their vicinity. They become crucial, especially in economically impoverished developing countries for lives and livelihoods and also for critical infrastructure. Malawi is possessed of 4 lakes, Malawi – 29600 km^2, Chilwa – 600 km^2, Malombe 450 km^2, and Chiuta – 130 km^2. One – Chilwa – is endorheic (no exit). Three – Malawi, Chilwa and Chiuta - are transboundary lakes while the largest lake – Malawi – happens to be the fourth largest freshwater lake by volume in the world and is third largest by area and second deepest in Africa. This sub-section will focus on Lake Malawi which comprises 20% of Malawi's total areal extent, as the lake has profound implications for the climate of the country and for climate change, resilience and adaptation. The largest of the feeder streams is the Ruhuhu, which flows into the lake from the east in Tanzania which shares Lake Malawi with Malawi and Mozambique. The border with Tanzania currently runs midway through the lake north to south although Malawi contests this and claims the whole lake.

Commenté [J[23]: Lake Malawi is not a hazard in and of itself. So it seems slightly add in this section. May want to rename or move to a different section

Commenté [LF24R23]: Therefore have moved to end of this section out of the rainfall and flood section

[57] Mtilatila et al (2022).

The highest proportion of inflow to the lake is from the Malawi side in the east which comprises 67% of the lake's catchment area,[58] supplying 55% of the lakes inflows,[59] flowing through rivers such as the Songwe (shared with Tanzania), North and South Rukuru, Bua, Dwangwa and the Linthipe/Lilongwe river system. Meanwhile, the only outlet to the lake is the Shire River at the southern extremity, which then flows south through southern Malawi to join the Zambezi south of the country. The Lake Malawi and Shire Basins are critical for the Malawian economy and for the human security of the Malawian population. They are also natural resource features that are exposed and vulnerable to climate change and variability and the impacts of extreme weather.

The level of the lake at the time this paper is going to press, is comparatively high – reported to have risen in April 2023 to 475.93m asl,[60] the highest point it has reached since May 1980 and 63 cm higher than at the same time in 2022.[61] At this level and above, there is a high risk of flooding around the lakeshores putting coastal strip agriculture and urban areas at risk.[62] It is against the law in Malawi to conduct agricultural activities below the 477m asl mark; in practice, this restriction is contravened in most lakeshore areas.[63] This high lake level, achieved in part, by the 3 consecutive La Nina influenced rainy seasons between 2021 and 2023, has taken local people by surprise as the trend since 1980 has been for diminishing lake levels. Many structures and resort facilities have been flooded, undermined and lost and damaged as a result of the lake rising unexpectedly.[64] Notwithstanding, if El Nino sets in deeply after 2023, as seems likely, the levels can drop away again just as easily.

Commenté [LP25]: Reference please

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Lake Malawi is a meromictic lake, meaning that the different layers of lake water do not mix, or very rarely do. The top layer, known as mixolimnion is quite shallow but contains most of the biodiversity of the lake which, because it does not mix with lower water layers (that are progressively starved of oxygen, the deeper it gets), is home to more fish species than any other lake in the world. The wild fish population is threatened by overfishing and by pollution and also by global warming.[65] Meanwhile, periodic drops in the level of the lake represents another threat driven by increasing extraction of water from the lake for socio-economic purposes, climate change, and deforestation. This also makes that top layer (mixolimnion) of Lake Malawi particularly vulnerable to atmospheric conditions and climate change and pollution from the contents of inflows from feeder streams.

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These inflows have, in recent decades, increasingly brought effluents from urban areas and chemical toxins from fertilisers together with (sediments) nutrient rich silt eroded mainly via topsoils from unprotected farmland as a result of deforestation, destabilising soils. As these sediments get deposited as the rivers slow down in their final stretches before emptying into the lake, the sediment gets deposited and causes blockage to flows into the lake and also forms outflow plumes in the lake where sediment builds up. These processes reduce space in the lake and exacerbate lake level reduction

[58] Sene, K. (2017) 'Long-term variations in the inflow record for Lake Malawi,' Hydrology Research (2017) 48 (3): 851–866.
[59] Bhave, A.G. et al. (2020) 'Lake Malawi's threshold behaviour: A stakeholder-informed model to simulate sensitivity to climate change,' *Journal of Hydrology*, 584.
[60] The Times of Malawi 8th June 2023 https://twitter.com/Times360Malawi/status/1666712540934447106
[61] Face of Malawi 19 April 2023: https://www.faceofmalawi.com/2023/04/19/rising-water-levels-on-lake-malawi-forces-out-tourism-businesses-along-the-lake/
[62] Bhave et al (2020)
[63] https://royalsocietypublishing.org/doi/10.1098/rsta.2021.0134
[64] Face of Malawi19 April 2023
[65] https://www.theguardian.com/global-development/2013/may/22/lake-malawi-water-levels-fish-stocks

during drying phases. The impacts of a drying lake have several ramifications including reduced water for human use, more concentrated pollution of the top layer where most biodiversity exists, killing species, and, when outflow from the lake becomes disrupted by lower lake levels, the supply of water to the turbines of the three hydro-electric power stations (Nkula (1966) Tedzani (1973) and Kapichira (the largest located in Chikwawa District)) located on the upper and Middle Shire, supplying the bulk (90%) of Malawi's electricity supply.

The Electricity Generation Company Ltd (EGENCO) is Malawi's national generation company with an installed capacity of 441.95 MW, as of March 2022. A total of 390.55MW is hydro-generated from the Shire River (88%) and 51.4 MW is from thermal diesel generators.66 This is against an estimated demand of over 529 MW.67 However, when the water level of Lake Malawi drops below the critical level of 471.5m asl, the Lake Malawi Outflow Threshold (LMOT - below which, no water passes into the Shire River), the amount of power generation decreases dramatically, and this leads to severe and prolonged power outages. A recent upgrading of the Kamuzu barrage and its operating rules has benefits, particularly in reducing lakeshore flooding risk but this does not help when water levels diminish. We obtain a wide range of results for the future, reflecting the deep uncertainty in climate model projections. While in some projections, lake levels rise, causing increases in the risk of lakeshore flooding, for many projections lake levels fall below the LMOT for significant periods of time, leading to 'no-outflow' conditions (see Figure 14). Analysing the implications of low lake levels on maintenance of the barrage and hydropower infrastructure could be an important issue worth exploring in terms of contingency planning and infrastructure management as energy is a central component of Malawi 2063.

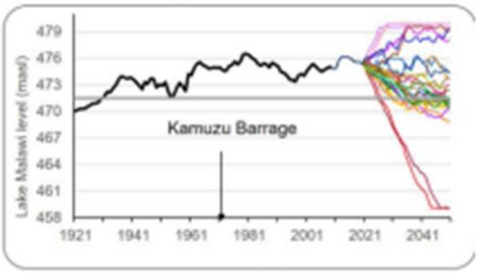

Figure 16~~22~~. Chart showing actual lake levels (black line) against LMOT (straight grey line) up to 2022 and projections from 2023 through to 2051. The uncertainty mirrors the level of uncertainty in rainfall projections. (from Bhave et al 2022).

Bhave et al (2022) assert that, *'Downstream of the lake, there is a decline in the satisfaction of Shire River performance metrics compared to the baseline. Of particular concern are very dry climate projections under which lake levels fall below the LMOT, when the barrage is no longer useful. These conditions would lead to a failure of the system, severely limiting the ability to satisfy hydropower and environmental flow metrics.'*68 What is meant here is that future projections based on the wide range of scenarios available show many predictions of lake levels falling below the level of which outflow

[66] JICA Position Paper (2022) found online at: https://www.jica.go.jp/Resource/malawi/english/activities/c8h0vm00004bpzlh-att/energy.pdf
[67] Ibid
[68] Bhave, A.G. et al. (2022) 'Stress-testing development pathways under a changing climate: water-energy-food security in the Lake Malawi-Shire river system,' *Philosophical Transactions of the Royal Society A*, 380

would be possible to supply the hydro-electric power stations on the Middle Shire, which correlates with the general prediction of a drying climate. Meanwhile, such a worrying forecast would be exacerbated by human forms of extraction from the lake and from rivers supplying the lake, especially the Songwe, shared with Tanzania and the Ruhuhu in Tanzania, extraction from the latter of which, Malawi has no control over.

Enhanced agricultural water demand and agricultural intensification reduces Lake Malawi inflows and results in slightly lower lake levels, and hence a marginally lower risk of lakeshore flooding. The four climate model projections with the highest rainfall cause the Lower Shire River to be flooded for between 5 and 20 per cent of the time, which is much more than under baseline conditions (1991-2020). Extreme rainfall in southern Malawi can lead to Shire River flooding, such as seen in 2015, 2019, 2022 and 2023, and potential future co-occurrence of high lake levels and high rainfall in the Shire River Basin would lead to very severe flooding in the lower Shire.69 Conversely, potential irrigation expansion in the Lake Malawi catchments could enhance the risk of very low lake levels and risk to Shire River hydropower and irrigation infrastructure performance. Improved regulation of lake outflows through the upgraded barrage does offer some risk mitigation, but trade-offs emerge between lake level management and downstream water, energy and food security requirements. These results highlight the need to balance Malawi's socio-economic development ambitions across sectors and within a lake-river system, alongside enhanced climate resilience.

Summary remarks on Lake Malawi risk factors

Lake Malawi is a vital natural resource for the country. The lake influences climate and weather across Malawi whilst climate and weather affect the lake and its adjacent (particularly the Shire River Basin) catchment areas. Reliance on the lake for livelihood activities such as fishing and for electrical power generation are therefore extremely vulnerable both as a result of human activity such as land use change and over-exploitation of the lake's biodiversity. For agriculture, in a predominantly rain-fed system of production as applies in Malawi to date, the Lake represents vast potential for irrigation but this needs to be balanced against other sectoral priorities such as energy generation and fisheries.

Storms with heavy rains and strong winds cause the top layer of the lake to become disturbed halting fishing activities and dispersing fish shoals. Heavy rain together with run-off from the Lake Malawi catchment basin also lead the lake to increase in height and threaten superstructure and installations around the lake, while drought and dry spells, especially and/or extreme heat, cause the lake levels to drop depriving vital sectors and services of water and disrupting transportation. In the case of extreme heat and dry spells, evaporation will increase, intensifying the reduction of water levels in the lake. Both of these eventualities have negative consequences for the SES. Both are likely to increase over the 3 projected time periods in the twenty-first century with one extreme alternating with the other, making development planning for energy security and for fishing and irrigation for agriculture on the coastal strip and the riverine zone of the Shire River Valley, precarious and vulnerable to loss and damage.

[69] Bhave et al (2022)

Overall Risk Summary – Climate hazards

In Annexes 1 to 8, individual district climate risk assessments are presented. In this section, overall climate hazard risk facing Malawi is summarised.

Mean temperatures are seen to have increased already by some 1.5 degrees C between 1850 and 2020 and may rise by between 1.7 (SSP 2-4.5) and 4.5 degrees C (SSP 5-85) by 2080. There will likely be an overall increase in the frequency and intensity of heatwaves. All models show an increase in the number of days with temperatures above 30°C (a threshold sometimes used to examine the sensitivity of maize to heat stress) and 35°C. Maximum, minimum and mean temperatures are likely to increase across the country, especially during the hottest months of October and November and especially in those areas that already experience the warmest conditions such as the Lower Shire Valley including Chikwawa District and also in the coastal plain of Karonga District.

There is high model agreement on temperature rise and increase in extra hot days and heatwaves. This prediction forms a backdrop to all other predictions of climate change in Malawi as atmospheric warming catalyses other forms of climate change and extreme weather.

This CRA notes that there has been a drying trend in recent decades and projects a drying climate throughout the country in the future which will be more pronounced in the North and South, catalysed by different climate drivers. There may be slightly increased rainfall in the Central Region. The percentage changes in annual rainfall are very small - +/- 5% by the 2040s, then, maybe the same (according to DCCMS) projections in the 2060s and 2080s but, according to modelling deployed by the Grantham Institute at the LSE (2017) may decline by up to 14% by 2090.[70] They are larger in specific seasons, for example drying of up to 10% is projected for September to October and wetting of up to 4% in December to February indicating a shift in emphasis towards the end of the rainy season.

Very wet years occurred in 1989, 1997, 2015, 2019, 2022 and 2023 while very dry years occurred in 1992, 2005 (driest on record) and 2008 and 2016. The occurrence of extreme wet and dry years is likely to increase and deepen on a gradient throughout the 3 prediction periods. In the models, there is strong agreement for decreases in the mean number of rain days and increases in the amount of rainfall on each rainy day (the 'rainfall intensity').Thus, while the number of beneficial, lighter rain events will decrease, the number of heavier rain events are indicated to increase, including from tropical cyclones, inducing even more storm damage than hitherto experienced. Floods of a devastating nature, more frequent and longer droughts with the dry season becoming essentially a drought season are thus, also likely to increase without adaptive action to enhance flood resilience. Taken together these changes suggest a more variable climate with a strong likelihood of back-to back crises – flood-drought, drought-flood.

Evaporation is likely to increase,[71] and this may lead to lower levels and volumes of surface water bodies, lower soil moisture, less humid air and demand and supply problems for water users. Therefore, if no action were to be taken, the overall water budget is likely to be threatened with consequent cascading impacts.

Commenté [LP29]: Reference please

Commenté [LF30R29]: Done

[70] https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/10/2772_Malawi_Summary_v4.pdf
[71] Mtilatila et al (2020), https://www.trocaire.org/sites/default/files/resources/policy/malawi-climate-change-case-study.pdf, https://thewashroom.waterforpeople.org/wp-content/uploads/sites/2/2021/07/Climate-Change-WRM-and-WASH-in-Malawi-Country-Case-Aug-2021.pdf,

There is high uncertainty concerning rainfall predictions which grows as one looks at projections for the 2040s to the 2060s to the 2080s. Incorporating uncertainty into decision-making approaches is essential for adaptation planning in Malawi.

The overall risk elements, therefore, in terms of climate change, nationally, during the forecast periods is of:

1. Warmer temperatures, minimum, maximum and mean
2. More and hotter extreme heat events
3. More storms with heavy winds and rains, especially in the South
4. Dryer winter seasons
5. More occurrence of drought with increasing length of dry spells, in short, a drying climate.

Figures 23, 24, 25 and 26 provide a skeleton flow approach to climate risk. In short they say that a climate hazard strikes and has immediate tangible manifestations of that hazard that are then exacerbated and/or ameliorated by sets of sensitivities and adaptive capacity, together referred to as factors of vulnerability and factors of exposure to multiply the impacts of the hazard across sectors and lead to further medium to longer term cascading impacts from which the element of risk is distilled which is shown as similar in all four climate hazard cases. It is from the full sets of factors of vulnerability distilled from primary and secondary research for this CRA that Adaptation Options reports for each of the 8 focus districts representing each Agricultural Development Districts (ADDs) will be compiled as a next stage of this process.

Commenté [J[31]: This applies to all of the climate risk flow charts: In sensitivity and exposure also consider the people - who is most exposed? Who is most sensitive?

Commenté [LF32R31]: Each one adjusted to reflect more of 'who is exposed.'

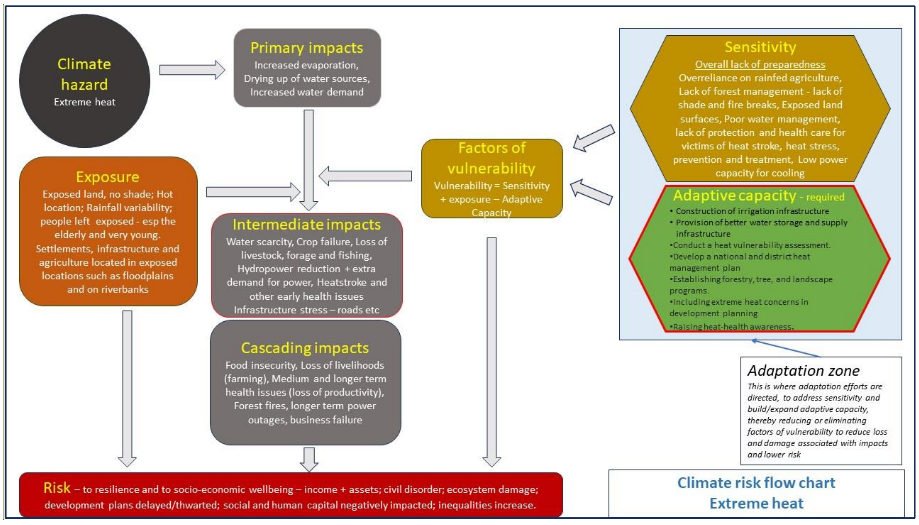

Figure 23. Climate risk flow chart for extreme heat, an under -rated climate hazard that is growing in potency and which has knock-on impacts in virtually every sector. Extremes of heat are, like extremes of anything, events outside of the usual norms and have the potential to derail development processes and inflict unanticipated loss and damage on unsuspecting social ecological systems (SES)

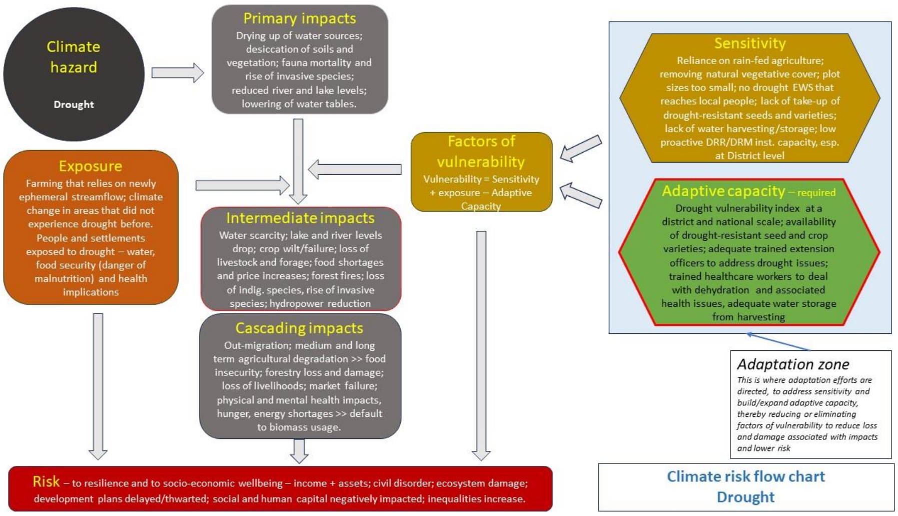

Figure 17~~24~~. Climate risk flow chart for drought which can be is a period of drier-than-normal conditions lasting for days, months or years. The key issue is the impact the drought has on ecosystem processes and the water budget essential for sustainable maintenance of the social ecological system in which the case study area is located. Drought is a slow onset climate event whose impacts may not always appear obvious but which harbour very long term implications.

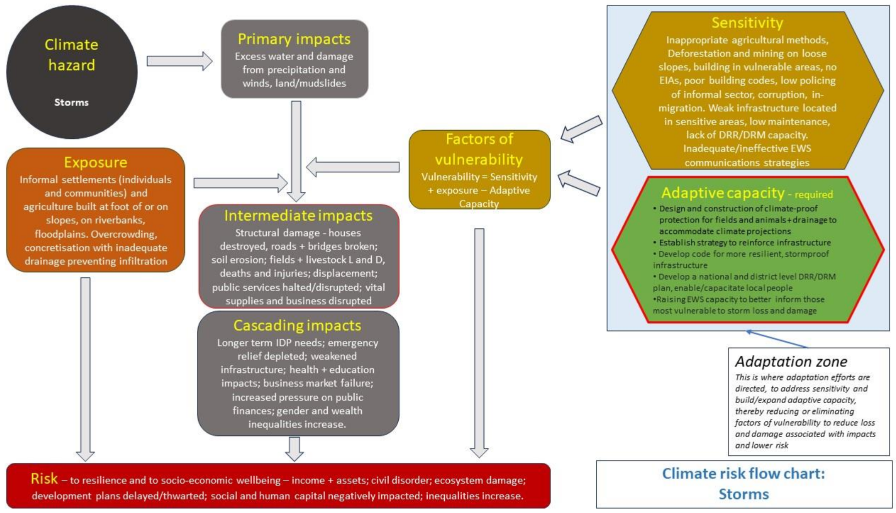

Figure 18~~25~~. Climate risk flow chart for storms, the severity of which are deepening and are likely to become a more permanentized feature of climate and weather as the 21st century progresses according to the climate projections upon which this study is based. The force of extreme storms, although short-lived, represents a hazard that has dramatic and long-lived consequences for the SES, often embodying changes to the balance of those systems.

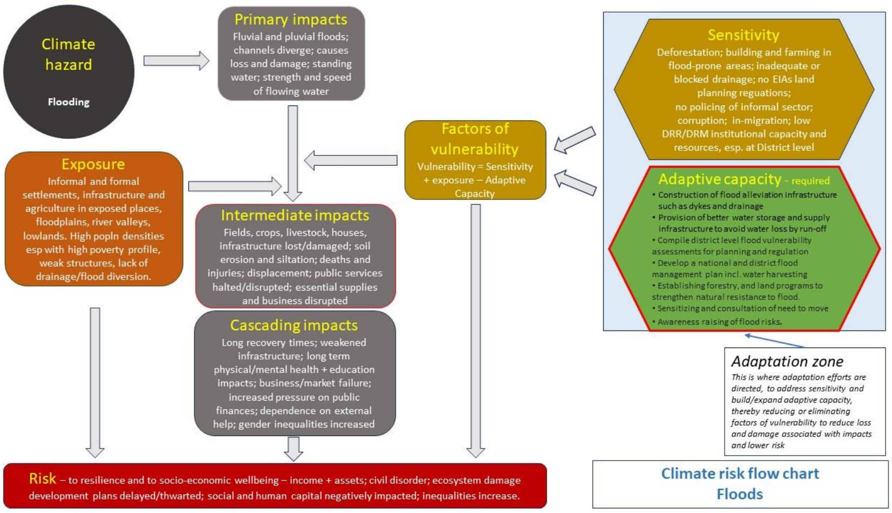

Figure 19~~26~~. Climate risk flow chart for floods which have been noted as the most impactful of all climate hazards in Malawi, causing most disruption of SES processes and for which most urgent relief is usually required because the impacts are immediately visible. Flooding is a rapid onset climate event that in certain circumstances can be a vital input such as in rice paddy in a floodplain while, in others, represents a catastrophe of huge proportions with strong multiplying effects.

4: Sectoral Risk Assessment

a. Agriculture – crop production

Agriculture is of central importance to the economy and human security of Malawi's 20 million people. Approximately 30% of Malawi's GDP comes from agriculture,[72] while 80% of the economically active population are involved in agriculture, 59% women and 41% men.[73] The agricultural sector in Malawi is dualistic, comprising smallholder farms and large estates. Of the 9.4 million hectares of land available for agriculture, about 32% is suitable for rainfed agriculture. On the large farming estates, the main crops are tobacco (60%) tea (20%), and sugar (18%) and the balance (2%) is used for growing other cash and food crops. Estate agriculture accounts for more than 25% of agricultural GDP, 10% agricultural employment, 9% of total GDP and 90% of export earnings. The estates access improved technologies and have better access to inputs, credit, supporting agricultural services and markets, hence have higher productivity levels than smallholders.

Commenté [LP33]: I believe the agriculture colleagues had shared a list of crops per districts, is there a reason why these crop projections aren't integrated here? The ToRs notably says "o Agriculture - crop production including maize and soya"

Commenté [LF34R33]: Have added on maize and soya

Commenté [LP35]: it's great to see some gender-disaggregated data, please use as much as possible

Commenté [LF36R35]: Sure!

i. Maize

As has been pointed out elsewhere in this report, maize is the major cereal crop grown in Malawi, grown as a staple food (mostly under rainfed conditions), covering more than 92% of the total agricultural area, and contributing 54% of calorific intake.[74] Maize production has been postulated as the principal occupation and major source of income for more than 80% of the total population in Malawi,[75] though this position is changing slowly as other crops, more tolerant to climate change, such as sorghum and soy, are experimented with.

Crop modelling results, for the short-term future, suggest that maize farming might benefit from CC as farmers strive to maintain and even improve yields to assuage the shortfall in meeting domestic demand.[76] However, faster crop growth could worsen Malawi's soil fertility problem especially in terms of nutrient content and soil moisture. Increasing temperature and, particularly, heat extremes, could drive lower maize yields in the medium to long-term future,[77] as could increasing occurrence and intensity of drought, as predicted in the climate projections by DCCMS (2023),[78] with predictions of between 10% and 20% reductions in yield occurring in the period 2050-2100,[79] most especially in the Central Region where much of Malawi's maize crop is currently grown,[80] (57% of the national yield on average 2011-2016).[81] The risk is outlined by Warnatzsch and Reay (2020):

> *While maize has an optimal growing temperature range that is higher than many other globally important grain crops, it is still sensitive to changes in maximum daily temperatures. Upper temperature threshold exceedances result in reduced photosynthesis and increased*

[72] https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA%20_Profile_Malawi.pdf
[73] https://malawi.unfpa.org/sites/default/files/resource-pdf/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report%20%281%29.pdf
[74] https://ascelibrary.org/doi/10.1061/9780784413548.156
[75] Ibid.
[76] Stevens, T. and Madani, K. (2016) 'Future climate impacts on maize farming and food security in Malawi,' *Scientific Reports*, 6, Article no. 36241
[77] Ibid.
[78] DCCMS (2023)
[79] Siamabele, B. (2021) 'The significance of soybean production in the face of changing climates in Africa,' *Cogent Food and Agriculture*, 7, 1.
[80] https://qz.com/2067056/how-climate-change-affects-soybean-and-corn-farming-globally
[81] https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=MI&crop=Corn

evapotranspiration rates, and therefore increased water demand. Furthermore, higher temperatures hasten the transition between phenological phases and reduce crop yields. Maize is particularly vulnerable to temperature anomalies during the flowering and yield formation stages of development, as higher temperatures decrease pollen germination and lead to shortened kernel filling and yield development. Maize is also drought sensitive, particularly early-on in crop development. A lack of water in early development can cause delays in crop flowering, reduced photosynthesis and decreased yield. Furthermore, low soil moisture tends to exacerbate the temperature stresses described above.[82]

The Malawian government introduced the Farm Input Subsidy Programme (FISP) after the severe drought of 2005. This helped to increase crop production and improve national food security mainly through improved access to fertilisers, however it is unlikely that this measure alone will be able to maintain food security in a changing climate (Msowoya et al., 2016). With limited finances and technology to cope with changes, and much of the economy, employment and food supply reliant on a predominantly rain-fed agricultural sector, without adaptation, maize production in Malawi is highlighted as being particularly vulnerable to future climate change (FAO, 2017, Giertz et al., 2015).[83]

Farmers across the country, consulted in the field mission workshops and visits attached to this work stated that, in recent years they have felt discouraged to increasing acreage to maize due to difficulties with selling crops for export due to government restrictions and also because maize is proving to be highly sensitive to climate change and because of volatility in market prices for maize from one season to the next, creating high levels of uncertainty.[84] Instead, farmers are turning to alternative crops, especially legumes, soy and cash crops such as ground nuts and cotton. If this trend were to continue, food security in Malawi will become increasingly dependent on the vagaries of international markets, the ability of the country to invest in substantial reserves of maize in good years or a transition in consumption of maize as the staple food crop.

ii. Soy

Soy is increasingly becoming an alternative food and cash crop in Malawi,[85] although, to date, soy is not a widely grown crop in Malawi, despite its reputed nutritional value. In a 2018 survey led by CIAT,[86] only 2% of cultivable land in the country was given over to soy.[87] In addition to this, confidence in the potential of soy as an alternative source of nutrition, particularly as protein, is low but growing in the face of threats to the viability of animal production, particularly in CC scenarios.[88] In a 2019 report, it is claimed that 'In Malawi, soy is a crop widely grown, but not widely consumed – many of its products are low quality or cost too much for families.' That said, considerable potential exists to change this

[82] Warnatzsch, E.A. and Reay, D.S. (2020) 'Assessing climate change projections and impacts on Central Malawi's maize yield: The risk of maladaptation,' *Science of The Total Environment*, 711
[83] FAO (2017) Malawi: Country Indicators [Online]. Available: http://www.fao.org/faostat/en/#country/130, Giertz, A. et al (2015) 'Malawi: agricultural sector risk assessment, 'World Bank Group Report No. 99941-MW
[84] https://www.reuters.com/article/us-malawi-farming-climatechange-policy-idUSKCN1AU048/
[85] http://www.aiccafrica.org/images/documents/Soybean_Outlook__April_-_Sept_2016.pdf
[86] CIAT - International Center for Tropical Agriculture
[87] CIAT; World Bank. 2018. Climate-Smart Agriculture in Malawi. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); [30], Washington, D.C. 30 p
[88] https://thepalladiumgroup.com/news/World-Food-Day-Is-Soy-the-Solution

value judgement which may have much to do with low crop management knowledge levels especially concerning processing.

The prospects for soy production under in the face of current CC scenarios are, meanwhile, considerably rosier than for maize. Soybean is shown to be resilient to temperature increases, whereas maize and cassava are not, leading to declines in crop suitability of the latter two.[89] The effects of climate change on soybean yields are mixed, as researchers find that soybean plants respond favourably to higher concentrations of CO2 in the air,[90] while untroubled by increasing temperatures up to a certain threshold. Soybean yields also may increase if farmers switch from other crops, such as maize, or expand into previously forested lands,[91] which, in the case of Malawi, would be highly undesirable.

Due to its higher climate resilience and multiple uses as well as its value for both food security and as a cash crop for export, the cultivation of soy has the potential to dominate agricultural growth in southern Africa. Malawi's climate projections of more variable rainfall but with increasing temperatures will suit soy but not in the lower Shire Valley as current varieties suffer die-back when ambient temperatures exceed 35^{o} C when soy suitability ratings plummet even below those of maize.[92] IN addition Soy s able to withstand certain amounts of drought, it is highly vulnerable to flood and inundation.[93] Many of Malawi's smallholder farmers who grow maize as a cash crop have diversified into legumes like soya and groundnuts, hoping for better market prices should one crop fail due to drought, trend that seems likely to continue as does crop rotation where maize in particular is rotated with soya.[94]

Many of Malawi's smallholder farmers who grow maize as a cash crop have diversified into legumes like soya and groundnuts, hoping for better market prices should one crop fail due to drought. But in addition to this, beans act as a nitrogen -fixing crop,[95] benefiting soil fertility in years when maize growing is given over to soy.[96]

Women and agriculture in Malawi - Women play an important role in the sector constituting 70% of full-time farmers, carrying out 70% of the agricultural work, and producing more than 80% of subsistence crops. Yet only 32% of agricultural landholders are women, 97 suggesting a gender imbalance towards land ownership and tenure. Large gender productivity gaps persist. Plots managed by men produce an average of 25% higher yields than plots managed by women. due to women having unequal use of land inputs, lower access to farm labour, inferior access to improved agricultural inputs and technology, and lower participation in the cash[98]/export crop value chains. The combination of

[89] Chapman, S. et al (2020) 'Impact of climate change on crop suitability in sub-Saharan Africa in parameterized and convection-permitting regional climate models,' *Environmental Research Letters*, 15.
[90] https://www.actionagainsthunger.org.uk/our-impact/stories/8-crops-endangered-by-climate-change
[91] Ibid.
[92] Chapman et al (2020).
[93] Siamabele, B. (2021) 'The significance of soybean production in the face of changing climates in Africa,' *Cogent: Food and Agriculture*, 7.
[94] Siamabele (2021)
[95] Siamabele (2021)
[96] https://www.reuters.com/article/us-malawi-farming-climatechange-policy-idUSKCN1AU048/
[97] https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA%20_Profile_Malawi.pdf
[98] https://www.worldbank.org/en/country/malawi/publication/unlocking-malawi-s-economic-growth-by-bridging-the-widening-gender-gaps-in-the-labour-

natural resource dependence and gendered differences in assets and resources means that women are typically more vulnerable than men to climate change.[99]

Over 85% of the population is employed in the agricultural sector in Malawi.[100] The country has an agro-based economy where 90% of agriculture is predominantly rain-fed.[101] As demonstrated in the preceding Climate segment, agriculture faces a heightened risk of water shortage, storm damage, drought, extreme temperatures leading to potential crop failure and vulnerability of livestock. There is, concomitantly, likely to be increasing demand for agricultural production, both for food security as populations, particularly in the urban areas, expand, and for export. There is likely to be increasing pressure on rain-fed farming but also on farmers who turn to irrigation. Pressure on crop production applies to all species but especially, maize (Malawi's staple cereal crop) and soya, crops that this CRA was asked to look particularly at. Malawi's maize output declined by 18.9% in the 2021/22 farming year due to a combination of factors like drought, tropical cyclones and inadequate supply of subsidized fertilizer.[102] The figures for 2022/23 look as if they will be worse, given the damage to harvests as a result of the impacts of Cyclone Freddy.

iii. Food security

There is increased risk of food insecurity as the country cannot feed itself at present, it is left exposed to global market forces and rising imports that affect balance of payments. Most of the Southern Region is projected by FEWSNET to be in food security 'Crisis' - IPC (Integrated Food Security Phase Classification) Stage 3 during the period September to January 2024.

Crisis Stage 3 is defined as:

> *Households that either:-*
>
> *Have food consumption gaps that are reflected by high or above-usual acute malnutrition;*
>
> *OR*
>
> *Are marginally able to meet minimum food needs but only by depleting essential livelihood assets or through crisis-coping strategies with over 20% of the population facing acute malnutrition and hunger-related mortality.*[103]

Other areas like Salima and Karonga are zoned as IPC Stage 2 but these are arbitrary delineations, food insecurity exists in most of the country, including urban areas like Lilongwe and Blantyre.

workforce#:~:text=Around%2059%25%20of%20employed%20women,than%20plots%20managed%20by%20women.

[99] https://www.futureclimateafrica.org/wp-content/uploads/2017/04/gender-agriculture-climate-services-brief-umfula-final.pdf

[100] Makate, C. et al (2019) 'Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa,' *Journal of Environmental Management*, 231, 858-868

[101] Ngongondo, C. *et al, '*Evaluation of spatial and temporal characteristics of rainfall in Malawi: a case of data scarce region,' *Theoretical and Applied Climatology,* **106**, 79–93

[102] https://www.reuters.com/markets/commodities/drought-tropical-cyclones-cut-malawi-maize-output-by-189-2022-07-15/

103 https://reliefweb.int/report/malawi/malawi-food-security-outlook-june-2023-january-2024?gclid=CjwKCAjwkNOpBhBEEiwAb3MvvWcwnmiHjjkSMdf1sbD3C4MHH6YsnmQIgl1CN1PWNmu5s5qXNTteUhoC-gwQAvD_BwE and, for an explanation of the classifications - https://fews.net/about/integrated-phase-Livestockclassification

Much of this food insecurity can be directly related to climate and weather perturbations while part of the explanation also lies in the agricultural systems employed by what is predominantly a subsistence smallholder farming network devoid of modern methods such as climate-smart technologies, equipment or skills/training.

Impacts on agriculture – crop production, can be grouped as follows:

1. Temperature increases and heatwaves create favourable conditions for pests and diseases for example, insects increase reproduction rates leading to pest infestation that damages crops. In the case of Malawi, the staple food crop – maize is vulnerable as warmer temperatures can engender maize stem borers and army worms which have already caused considerable loss and damage in the first two decades of the 21st century. Higher temperatures, especially in the Southern Region can reduce flowering and pod formation in soya plants. Increased evapotranspiration as a result of excessive heat can also destroy crops. With hotter temperatures there exists a risk to crop diversity as some crops will not be able to adapt and biodiversity loss will also reduce yields.

2. Dry spells, drought, reduced rainfall patterns both now and projected - articulate increasingly erratic behaviour leading to enhanced evaporation, soil moisture deficiency and water shortages for irrigation. Drying soils may result in crop failures, reduced yields and food insecurity. Increased water stress due to extended dry periods and droughts have the potential to halt soya growth and development.

3. Farmers in Malawi rely mostly on rain-fed agriculture and unpredictable rainfall as exists currently and is likely to increase in future can disrupt planting and harvesting schedules, leading to lower crop yields. Changes in rainfall patterns create ideal conditions for the spread of fungal diseases such as maize rust, soybean rust and maize ear rot. The sheer power of heavy rainfall can strip the leaves from vegetation such as fragile crops while winds can fell trees.

4. Increased occurrence of heavy rainfall and frequency and intensity of floods leading to destroyed and washed away crops, especially seedlings, topsoil erosion and washing away into streams, damage to farm infrastructure such as wells, irrigation equipment, vehicles and housing. Erosion is partly a function of the agricultural practices employed. Storms that occur at the end of the rainy season such as cyclones arriving from the Indian Ocean, have the potential to wipe out harvests. Changes in rainfall and standing water can also encourage waterborne diseases that affect crops and livestock.

Risk summary – (agriculture: crop production)

Overall, climate change directly impacts the agricultural productivity of small-scale farmers who have weak fall-back strategies in the face of exogenous shocks such as climate change and extreme weather. Agriculture depends largely on climate related factors such as sunlight for photosynthesis, rainfall for moisture and ambient temperature. A majority of Malawians seek their livelihoods from agriculture. Changes in variability, seasonality, rainfall regimes, water availability, heat, and the emergence of new pathogens and diseases, all predicted in this study, increase risk to farmers and make their livelihoods more vulnerable threatening both food security and, because agriculture contributes 22% (2022) to national GDP,[104] the economic wellbeing and potential of the country. Production losses of varying

[104] https://www.statista.com/statistics/520594/share-of-economic-sectors-in-the-gdp-in-malawi/

magnitudes may result from increased frequency and intensity of extreme events, such as floods, droughts, heatwaves, and windstorms.

Extreme weather of any kind acting either alone in tandem or back-to-back can cause damage to natural ecosystems which do not have time to recover their balance before the next climate catastrophe strikes, reducing habitats for beneficial insects, pollinators and other organisms beneficial for agriculture. The agriculture sector is crucial to Malawi's development future and commercialisation of agriculture is one of the 3 pillars of the Malawi 2063 development strategy.[105] Agriculture is the most impacted sector by climate and weather and, due to its reliance on natural resources, quite possibly, the most vulnerable. A host of strategies have been attempted and promoted to address the challenges of climate change and extreme weather in agriculture to address agricultural productivity and food insecurity in Malawi and these will be explored in the Adaptation Options segment of this task. These include climate smart agriculture, novel methods of soil management, climate resilient crop varieties, improved water management, and better disaster preparedness.

The risk element centres around the worsening threat to yields and overall crop production by a combination of poor agricultural practices, over-exploitation of the land, lack of commercialisation and mechanisation crosscut by climate change and extreme weather patterns that look set to exacerbate an already vulnerable sector.

a. Agriculture - livestock

Livestock is an underfunded but key contributor to GDP and to food security in Malawi representing a little under 40% of the agriculture sector.[106] Concomitantly, livestock also represented 24% of Malawi's greenhouse gas emissions.[107] Keeping livestock and profiting from it is a challenging livelihood activity in Malawi given that, amongst smallholder farmers, the average farm size is just 0.7 ha and almost two thirds of smallholder farmers cultivate less than 1.0 ha of land.[108] This presents immediate constraints for the keeping of livestock unless it is able to be housed or unless grazing is available on other farmers' land. A key issue for raising of livestock is meeting food requirements. The small size of farms constrains farmers from growing pasture crops when they have difficulty meeting household food needs. Climate change and extreme weather events have significant impacts on livestock in sub-tropical countries like Malawi, affecting the health, productivity and wellbeing of animals, which can, in turn, have food and economic implications. Some of the key impacts include:

1. Heat stress – rising temperatures and extreme heat events can lead to heat stress in livestock and even kill some breeds that do not have coping capacity for increased temperatures. Heat stress can stunt growth, reduce animal productivity, including things like milk and egg production. Commonly observed responses to heat stress include reduced feed intake, shade seeking, increased sweating and panting, increased water intake and drinking frequency, increased standing time and decreased lying time, and reduced defecation and urination frequency, all negatively impacting animal health.[109]

2. Droughts – risk of water scarcity for livestock, especially where little water storage exists, leading to dehydration and reduced animal health.

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105 GoM (2020)
106 https://winrock.org/document/green-investment-opportunities-for-malawis-livestock-sector/#:~:text=Livestock%20plays%20a%20major%20role,which%2037.4%25%20comes%20from%20livestock.
107 Ibid.
108 https://www.ccardesa.org/malawi
109 https://www.mdpi.com/2073-4433/13/1/140

3. Floods can have serious repercussions for livestock as animals are vulnerable to being swept away and killed or injured with great difficulty in recovery. In this process, livestock may get displaced, resulting in cost and difficulties in recovery.

4. Health and reproduction – climate change and extremes weather have health implications for livestock diseases. Heat and nutritional deficits can negatively impact the immune systems of livestock and reproductive performance, the latter leading to lower birth rate and threats to animal populations with consequent effects on livestock farmers.

5. Forage – Changes in rainfall patterns and more frequent and longer dry spells can affect the availability of natural pasture and lead to forage scarcity, leaving livestock challenged to access sufficient food. Sustained exposure to such conditions can have serious health consequences with malnutrition, enhanced vectors of disease including lung diseases, tick-borne disease and parasitic infections. Changes in climate regimes can also favour the introduction of invasive plant species that can negatively affect forage and food for livestock.

6. Transhumance and grazing patterns – changing climate conditions, especially a drying climate can disrupt livestock migration and grazing with potential conflictual situations arising where livestock stray onto settled farmland being used by crop cultivators. There can be overgrazing in some areas and underutilisation of pasture in other cases.

i. Forage

As noted above, a key component for the raising of livestock is the ability to provide sufficient appropriate food and, into this equation comes forage. Forage can be loosely defined as plants eaten by the animals as pasture, crop residue, or immature cereal crops, but it is also used more widely to include similar plants cut for fodder and carried to the animals, especially as hay or silage.[110] Given the increase in population in Malawi, and the competition for cultivable land, as was mentioned earlier in this report, apart from the few commercial farmers, plots are mostly of less than 1.0 ha and this means that the availability of natural forage has suffered considerable diminution. Climate change and extreme weather acts on this factor of vulnerability, affecting livestock grazing and forage dependent agriculture, creating risk in various ways:

1. Storms and changes in rainfall – can lead to soil erosion which damages pastures and reduces their productivity. This can make it difficult for forage to regenerate and recover.

2. Dry spells and droughts - can lead to reduced forage availability and a scarcity of food for livestock. In Malawi this problem will be exacerbated by the predicted drier winters (May to October) and more intermittent rainfall.

3. Increasing and extreme temperatures – can lead to die-back of forage with reduced nutritional content making it less suitable for livestock nutrition. Extreme heat events can lead to tissue senescence (interruption of regular cell processes) that strongly decrease forage quality. Under moderate heat stress, plant maturation is faster, water content of plant tissues decreases.[111]

[110] Fageria, N.K. (1997) *Growth and Mineral Nutrition of Field Crops*. Marcel Dekker, NY, NY: p. 583.
[111] https://hal.science/hal-01611403/document#:~:text=Ecophysiological%20changes%20in%20plants%20in,tissues%20decreases%20while%20WSC%20increase.

4. Overgrazing – as forage becomes scarcer, livestock owners may concentrate their animals on less forage resulting in overgrazing, contributing to soil erosion and land degradation.

5. Invasive species – as traditional forage species die away in changed climatic conditions, these changed conditions may favour the proliferation of alien invasive species that colonise pastureland but which are not suitable for livestock forage, once again, engendering competition between native and invasive species, threatening the food budget of livestock.

6. Economic impact – livestock keeping is an essential source of income for many communities on Malawi, often being a component of subsistence and survival along with crop production, fishing etc. Reduced availability of quality forage can decrease livestock productivity resulting in economic consequences – lower dairy and meat production, reduced incomes, food insecurity and livelihoods for poor rural communities.

Risk summary – (agriculture: livestock)

With livestock, whilst animals are impacted by climate change, it is also true that livestock are a driver of climate change. In pastoral and agropastoral systems such as exist in Participative Forestry Management practices in Malawi, livestock is a key asset for poor people, fulfilling multiple economic, social and risk management functions. The impact of climate change can heighten the vulnerability of livestock systems and reinforce existing stress factors affecting livestock production systems, such as rapid population and economic growth, rising demand for food (including meat) and animal products such as dairy, and conflict over scarce resources (land, water, biofuels, etc). There is also heightened risk of increased spread of existing vector-borne diseases and macroparasites, accompanied by the emergence and circulation of new diseases.112 In some areas, climate change may also generate new transmission models. For rural communities, losing livestock assets could trigger a collapse into chronic poverty and have a lasting effect on livelihoods.

Various strategies may be considered to mitigate the negative impacts of climate change and extreme weather on livestock. These include improved livestock practices, climate resilient livestock breeds, and early warning for livestock disease outbreaks. A well-staffed, adequately trained and resourced extension service would be necessary for this. In all districts visited for this CRA, lack of sufficient and adequately trained and resourced livestock extension officers was a constant complaint. Climate-smart agriculture and sustainable land practices can help improve forage availability and enhance the resilience of livestock farming.

b. Forestry

Forest cover in the Lake Malawi Basin decreased from 47% in 1995 to 36% in 2005 (see Figure 27 below),[113] and continues at an annual rate of between 1 and 2.5 % of its total annually,[114] the highest rate of deforestation in Southern Africa.[115] This forest loss can be mainly attributed to agricultural expansion and excessive use of biomass, such as wood, charcoal, and agricultural residues, mostly used for cooking and heating'.[116] the underlying driving factors associated with deforestation are expansion of agriculture, biomass used for energy, expansion of tobacco growing, and brick burning.

Commenté [J[37]: A forest cover map would be useful here.

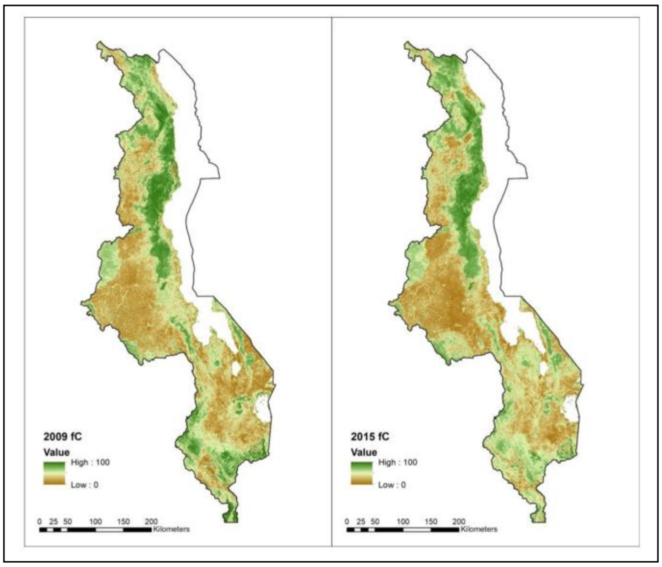
Commenté [LF38R37]: Done

Commenté [LP39]: @Julie Greenwalt if you disagree with some of my comments please feel free to let me know

[112] https://www.unccleam.org/wp-content/uploads/library/ifad81.pdf
[113] Calder, I.R. et al (1995) 'The impact of land use change on water resources in sub-Saharan Africa: A modelling study of Lake Malawi,' *Journal of. Hydrology,* 170, 123–135.
[114] Ngwira, S. and Watanabe, T. (2019) 'An Analysis of the Causes of Deforestation in Malawi: A Case of Mwazisi
[115] Ngwira, S. and Watanabe, T. (2019) 'An Analysis of the Causes of Deforestation in Malawi: A Case of Mwazisi,' *Land* 2019, 8, 48, 2.
[116] Ibid

Fire is another problem (see below) but only accounted for 0.59% of tree loss from 2001-2002).[117] Biomass accounts for 88.5% of the country's energy demand, 6.4% comes from petroleum, 2.8% from electricity (hydro power), and 2.4% from coal. In 2010, remaining forest cover was estimated at between 32 and 34%, calculated from satellite photographs, with around 29% consisting primary forest, the most biodiverse and carbon-dense form of forest.[118]

A further factor to consider with forestry in Malawi is that of degradation as opposed to deforestation. Degradation is defined by the IPCC as "a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity, or value to humans. Forest degradation is land degradation that occurs in forest land. Deforestation is the conversion of forest to non-forest land and can result in land degradation." [119] Forest disturbances by human activities in subtropical and tropical forests and woodlands occur as a gradient of severity, from complete forest conversion to various degrees of degradation within forests. While deforestation results in complete change from forest cover to another land cover, degradation occurs without removal of the forest canopy nor as a change in the land cover. Skole et al (2021) show that the rate of degradation of forests in Malawi far outstrips that of deforestation and is increasing dramatically.



117 https://www.globalforestwatch.org/dashboards/country/MWI/?category=fires
118 https://rainforests.mongabay.com/deforestation/2000/Malawi.htm
119 IPCC, 2019 *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland

Figure 27: Fractional forest cover for the years 2009 and 2015 – darker greens being the most concentrated. Note the extensive forest loss in the south in this short period (adapted from FAO (2013) Atlas of Malawi Land Cover and Land Use Change, 1990 p.20

Degradation in Malawi is very high in focal districts in this CRA such as Kasungu, Rumphi and Chikwawa a district that suffered 13% of all forest degradation in the country between 2010 and 2015.[120] Meanwhile, in the same period, the Southern Region has suffered the brunt of damage to forestry with deforestation accounting for 35% of deforestation and 50% of forest degradation, compared with 14% and 11% respectively between 2000 and 2009.[121] As the Southern Region is also experiencing the highest density and increase in population and the highest rates of negative impacts of climate change and extreme weather compared with the Central and Northern regions, and the gradient of impacts is becoming steeper, this raises serious concerns for urgent attention to resilience and adaptation for the Southern region.

Climate change and extreme weather have significant impacts on forests just as deforestation has significant impacts on climate change and resultant cascading impacts. Some of these are as follows:

1. Dryness, drought and heat – higher temperatures and prolonged period of low or zero rainfall contribute to risk of fires in forests in Malawi. Such fires can destroy large tracts of forest, degrade forest ecosystems including wildlife habitats and release large quantities of carbon dioxide into the atmosphere. It can also lead to forest die-back and reduced tree cover and reduces biodiversity. Prolonged dry spells and droughts can weaken trees and make them more susceptible to pests and diseases due to water shortage. It can also lead to forest dieback and reduction of forest cover. But there are other connections between drought and forests in Malawi. When drought occurs, it constrains agricultural activity and farmers – especially if they are located close to large urban areas, turn to the one other livelihood activity guaranteed to bring an income, however small – charcoal production and cutting of trees for firewood (see the report in the footnote below for an example).[122]

2. Rainfall variability - erratic rainfall patterns and temperature fluctuations can hinder the regeneration of tree species, making it challenging to maintain healthy and diverse forests. Meanwhile, heavy rain for example, during storms has the potential to strip trees of leaves whilst heavy winds blow trees over.

3. Soil erosion – Malawi has a very serious soil erosion problem as has been described in this report. Forested areas are not exempt from this problem. Soil erosion in Malawian forests diminishes the health of the forest and contributes to siltation of water bodies. When land is deforested, it immediately becomes vulnerable to soil erosion and this is one of the greatest factors in the siltation of rivers and stream and export of silt to the lakes of Malawi.

4. Carbon – forests act as carbon sinks, helping to mitigate climate change by absorbing CO_2 from the atmosphere. Between 2001 and 2022, forests in Malawi emitted 4.27 $MtCO_2e$ per year, and removed - 5.19 $MtCO_2e$ per year. This represents a net carbon sink of - 915 $ktCO_2e$ per year.[123] Climate change impacts, which include drought and related wildfires, can reduce the

[120] Skole, D.L. et al (2021) 'Direct Measurement of Forest Degradation Rates in Malawi: Toward a National Forest Monitoring System to Support REDD+,' *Forests*, 12, 426.
[121] Ibid
[122] https://www.nytimes.com/2016/08/21/world/africa/poverty-drought-malawi-water-supply.html
[123] $MtCO_{2e}e$ means million tonnes of carbon dioxide equivalent, $ktCO_{2e}$ means thousands of tonnes equivalent https://www.globalforestwatch.org/dashboards/country/MWI/?category=climate&location=WyJjb3VudHJ5IiwiTVdJIl0%3D

ability of forests to sequester carbon, potentially contributing to higher atmospheric carbon levels.

5. Water – forests play a vital role in absorbing and retaining water and distributing water around the forest ecosystem. Disrupted rainfall can quickly lead to reduced water availability and increased pressure on watersheds.

6. Economic impacts – the forestry sector in Malawi provides livelihoods for many communities through activities such as timber production, non-timber forest products (fruit, mushrooms agroforestry, small livestock) and ecotourism. Climate related disruptions can negatively impact the income and livelihoods of these communities who depend on these activities.

i. Forest fires

This CRA was asked to look specifically at the occurrence and risk of fire to forests in Malawi. As noted above, fire constitutes less than 1% of tree loss in natural forests in Malawi.[124] Fires were responsible for 0.27% of tree cover loss in natural forests in Malawi between 2001 and 2022.[125] However, the occurrence of fire is increasing in scale (see Figure 28). As can be observed, the rate of increase of tree loss from forest fires has been increasing throughout the 21st century to date and can be correlated at least partly, to climate change, specifically to a warming and drying climate as well as to accidental fire and arson by those wishing to increase land for farming. The fire season corresponds with the dry season in Malawi with most fires occurring between July and November when the forest litter and undergrowth is at its driest and when searing heat and sunlight can ignite dry tinder.[126] Fire damages forests in Malawi over a longer term when one considers that most of the young trees and saplings can be destroyed.

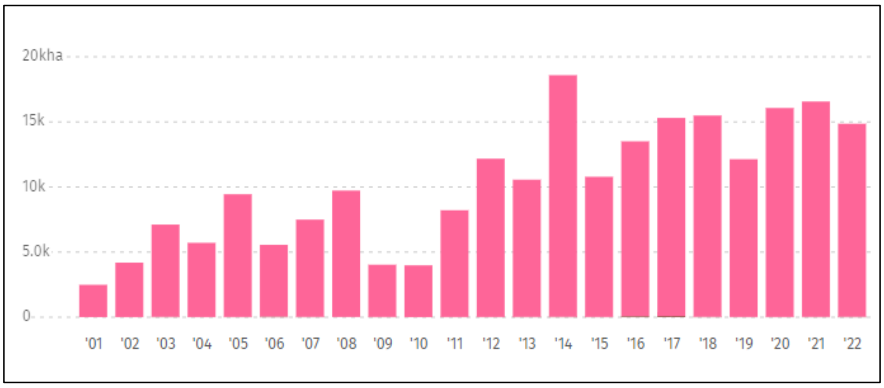


Figure 28. Tree cover loss due to fires in Malawi. From 2001 to 2022, Malawi lost 594 ha of tree cover from fires and 223 kha from all other drivers of loss. The year with the most tree cover loss due to fires during

[124] https://news.trust.org/item/20120103113300-q5z2u/
[125] https://www.globalforestwatch.org/dashboards/country/MWI/?category=fires
[126] https://news.trust.org/item/20120103113300-q5z2u/ and https://www.globalforestwatch.org/dashboards/country/MWI/?category=fires

this period was 2017, following a deep and prolonged drought in 2016, with 90 ha lost to fires — 0.59% of all tree cover loss for that year.

Risk Summary – (forestry sector)

The risk of increasing forest fires and deforestation by all means, remains very high whilst ever there is reliance on biomass for energy across the country. Even for those lucky enough to have access to the national grid, there are so many power cuts and load shedding that households normally always purchase charcoal and woodfuel in the eventuality of being cut off from the power supply and having no other sources of energy.[127] Indeed, urban areas represent the greatest demand for charcoal and fuelwood, this being despite the fact that charcoaling is illegal in Malawi. During the field mission for this work, whenever travelling between focus districts, a constant flow of bicycles loaded with charcoal or woodfuel could be observed pedalling in the direction of towns and, away from the towns themselves, charcoal was readily available for purchase at the roadsides.[128] As climate change is so closely aligned with deforestation, it becomes incumbent on decision makers to approach adaptation with regard to forestry and deforestation with novel approaches to solving the energy crisis in the country.

Commenté [LP40]: Reference please. Also are there available statistics to refer to?

Commenté [LF41R40]: Done

Commenté [LP42]: Other reference to provide?

Commenté [LF43R42]: Done

To address these challenges Malawi has developed policy strategies and promotes reafforestation and afforestation programmes, sustainable forest management, agroforestry and conservation efforts. Even with these efforts, deforestation continues apace for the reasons stated above. Thus, a fundamental re-think on community forest management may prove useful.

e. Fisheries

Fisheries risk assessment

Climate change and extreme weather have considerable impacts on fisheries in Malawi as elsewhere in the world. Lake Malawi contributed between 75% and 94% of the nation's total fish production (there are widely differing estimates).[129] And yet, fish stocks in Lake Malawi, the third largest lake in Africa, declined by up to 93 percent between 1990 and 2010 and, based on anecdotal reports from locals, the situation appears to have deteriorated further since then.130 Fishing communities in the north of the lake, such as Karonga, have been particularly badly hit.131 Lake Chilwa, a much smaller shallow lake in the south east and not in the Rift Valley, had been known, as recently as 2001, to produce one third of Malawi's fish catch, economically sustaining over 6,000 fishers,[132] but that was before the lake started drying up more frequently, destroying the fish stock, partly as a result of climate change. Fish comprise over 25% of protein intake for the country.[133] This has reduced from 60-70% in 1990,[134] when the population (9.5 million) was less than half what it is today. Fishing, meanwhile, contributes 7.2% of GDP (2019). Fish is an important factor in food security. Yet, the lakes are being

[127] https://bracc.kulima.com/news-blogs/investing-clean-energy-sources-key-curbing-malawis-deforestation , https://africabrief.substack.com/p/malawis-electricity-crisis-curse, https://www.theguardian.com/global-development/2017/dec/13/malawi-power-cuts-national-blackouts-poor-hungry

[128] https://www.ft.com/content/66801d61-efd8-4079-abcb-0723ea267c82

[129] https://agrilinks.org/sites/default/files/resource/files/malawi_file.pdf and https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/5358/0ab45416ac19a2926e2c4cbae24d6ff3.pdf?sequence=2#:~:text=The%20contribution%20of%20fish%20to,GDP)%20is%20about%204%25.

[130] https://reliefweb.int/report/malawi/lake-malawi-s-dwindling-fish-stocks-threaten-livelihoods-0

[131] Ibid

[132] https://www.ramsar.org/news/community-based-natural-resources-management-case-lake-chilwa-wetland-malawi#:~:text=In%20normal%20years%2C%20one%20third,trade%20on%20its%20salty%20waters.

[133] Ibid and https://core.ac.uk/download/pdf/234647975.pdf

[134] http://www.sdnp.org.mw/enviro/action_plan/chap_3.html

overfished and are highly exposed to climate change and extreme weather events which are increasing in frequency and magnitude as noted elsewhere in this report.

The per capita fish consumption in Malawi fell by more than 60 per cent, from 14 kg per person per year in the 1970s, to about 8 kg in 2015 due to a decrease in fish supply and rapid population growth over the years.[135] This has serious repercussions for health and wellbeing in a society where most people cannot afford to buy meat.[136] The diagram below in Figure 29 provides an idea of how fish production has evolved in recent years. From this it can be seen that there have been significant increases in catches and, despite the considerable encouragement and hype, it can also be seen that aquaculture is still in its infancy in the contribution it makes. Nevertheless, aquaculture production grew from less than a thousand tonnes in 2005 to more than 12 200 tonnes out of a total catch of 199,500 tonnes in 2017,[137] mainly with extensive pond culture, often integrated with agricultural activities on farmsteads. Three species of tilapia accounted for more than 95 percent of production.[138] Yet Capture fisheries are most vulnerable to the impacts of climate change, those increases in production have been made at the expense of the biodiversity and future fish stocks of the lakes and rivers of the country. Figure 30 shows which parts of the lake are most degraded and a further implication is made by the pie-charts that show that degradation increases, the more sophisticated the fishing equipment is.

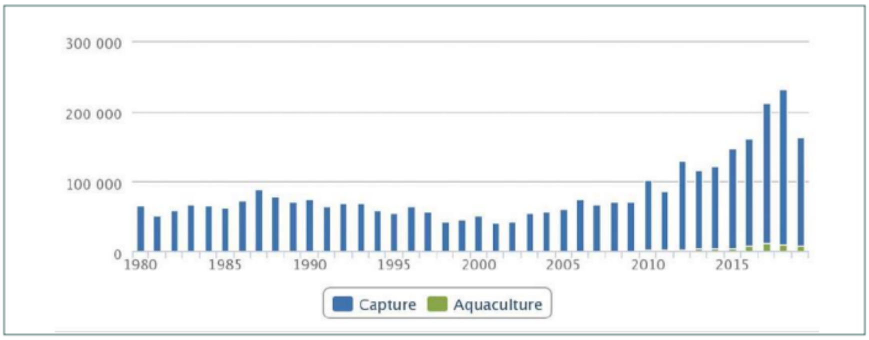


Figure 29. Total Capture and Aquaculture Production in Malawi (1980-2019) (Tonnes), from FAO.139 Note the miniscule contribution to date from aquaculture though the sub-sector is growing rapidly.

135 Nankwenya, B. et al (2017) 'The Demand for Fish Products in Malawi: An Almost Ideal Demand System Estimation,' *Journal of Economics and Sustainable Development*, 8, 16.
136 https://reliefweb.int/report/malawi/lake-malawi-s-dwindling-fish-stocks-threaten-livelihoods-0
137 https://www.fao.org/figis/pdf/fishery/facp/MWI/en?title=FAO%20Fisheries%20%26%20Aquaculture%20-%20Fishery%20and%20Aquaculture%20Country%20Profiles%20-%20The%20Republic%20of%20Malawi
138 Ibid
139 https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/5358/0ab45416ac19a2926e2c4cbae24d6ff3.pdf?sequence=2#:~:text=The%20contribution%20of%20fish%20to,capture%20fisheries%20(FAO%202022).

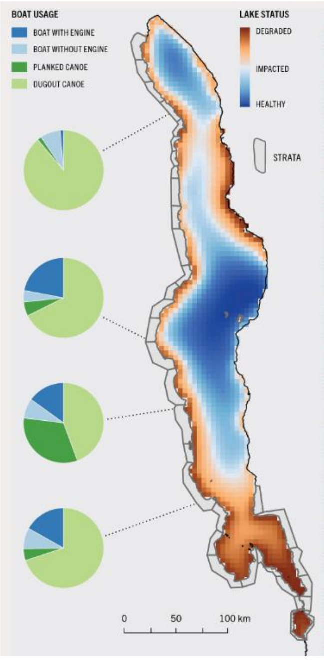


Figure 30: An FAO 2022 representation of the status of Lake Malawi fisheries, showing the most degraded areas closest to the shoreline and in the south where most fish catches are obtained. *

*This image also shows (in the pie-charts) that the more sophisticated the fishing equipment, the most serious is the degradation. Use of inappropriate fishing gear together with overfishing is responsible for much of the degradation close to the shoreline.[140] Climate change, as in so many other instances of negative stressors acts as an exacerbating agent to pre-existing social factors of vulnerability that add potency to the impacts. Thus, when developing appropriate adaptation strategies, one must take into account the full range of vulnerabilities in order to address climate and weather.

Climate change and extreme weather have significant impacts on fisheries in Malawi, particularly in its lakes and rivers. Fisheries are crucial for the livelihoods and food security of many Malawians, making these impacts particularly concerning. Some of the key impacts are as follows:

Commenté [J[44]: ?

Commenté [LF45R44]: Rivers, amended

1. Increasing temperatures and extreme heat – rising temperatures in the region and extremes of heat have impacts on water quality. Most fish in the lakes as well as the rivers, live in shallow water where atmospheric heating has most effect on water temperatures. This affects fish behaviour (for example, spawning), distribution and growth. Some fish species are more sensitive to temperature change than others but fish can die in warming water as their physiologies cannot handle the change. Warmer waters, combined with pollutants entering the ecosystem enhance disease and parasites. Combined with other changes such as nutrient composition, changes in water temperature can disrupt reproductive cycles and growth patterns of fish species. The end result is decreased fish stocks and variety and reduced catches.

[140] https://www.fao.org/3/cc0461en/online/sofia/2022/status-of-fishery-resources.html

2. Cascading impacts of other climate induced stressors – climate change can contribute to the decline of fish stocks through overfishing when other livelihoods, such as agriculture fail due to unanticipated drought or flood and people who are not primary fishers turn to fishing. This impacts fishing communities both in food security as most fishers are subsistence fishers and fish traders who are mostly women.

3. Heavy rain and flooding – disrupts fish migration patterns. Heavy run-off into water bodies also brings with it toxins and invasive species, pathogens and diseases, competition for space in the water increases and fish desert areas where they previously migrated to. Run-off from heavy rain also leads to fluctuations in water levels, as seen by the unexpected recent rise in Lake Malawi levels with increasing water turbidity which can have the effect of suffocating fish.

4. Winds -a warming climate induces extreme weather which brings with it stronger winds and gusts which get magnified over a large water surface like Lake Malawi. Most fishers are risk-averse when it comes to venturing into high winds and waves. 141 Small scale fishers generally use flimsy boats or pirogues and can be superstitious about unusual winds. Changing wind conditions may, therefore, reduce access to fish which may have implications for food production and trading.[142] Because many small-scale fishers sell any surplus after subsistence to market traders or dealers from the large urban areas, loss of fishing could reduce income for households and lead to loss of livelihood assets.

5. Invasive species – as mentioned above the introduction of invasive species, which can out-compete with and displace native species may eliminate traditional food species and replace with species that people will not eat. This is particularly the case for fish farming where the introduction of invasive species to a fishpond which has been carefully controlled to encourage the concentrated growth and farming of tilapia, can be destroyed with total loss as was explained to team members of this CRA on field mission visits to women fish farmers.

6. Economic impact – as noted above, fisheries contribute significantly to Malawi's economy and are a major source of employment and income for communities living near water bodies (capture and farmed). Reduced fish catches and reduction in species have knock-on impacts on markets and the larger economy, leading to unemployment and, as mentioned above, food insecurity, especially amongst fishing communities.

7. Ecosystem services – healthy freshwater fisheries are crucial in maintaining the overall health of aquatic ecosystems. Declining and less healthy fish populations disrupt the balance of these ecosystems, affecting water quality and the availability of other ecosystem services.

Risk summary (fisheries sector)

The sustainability of the fisheries sector in Malawi is a much-underestimated subject. Fisheries are a vital sector for all the reasons stated above which can be summarised under the headings of livelihoods, food security and biodiversity. Without climate change and extreme weather, the sector was already endangered because of inappropriate methods, overfishing and lack of management/policing of the industry. Climate and weather changes have exacerbated these tensions and stressors, revealing the interconnectedness between fishing and other sectors such as agriculture

[141] Sainsbury N. C. et al (2021) 'Trade-offs between physical risk and economic reward affect fishers' vulnerability to changing storminess. '*Global Environmental Change,* 69.
[142] https://www.frontiersin.org/articles/10.3389/fmars.2022.841048/full

and forestry and intensified the pressure exerted by these stressors acting in tandem. Further atmospheric warming, as predicted in all climate scenarios, in addition to the prevalence of inappropriate fishing methods and overfishing, increase the existing risk of disease and further extinction of species from warming waters leading to loss of livelihoods, impacts on food security and pressure on other activities such as agriculture and charcoal burning and selling. Further heavy rain storms and floods may add further toxicity and turbidity to waters that have already suffered pollution. Increasing dry spells and drought coupled with increased extraction of lake and river waters for irrigation of agriculture and water to supply urban infrastructure may result in reduced lake levels which will concentrate the risk of fish disease and morbidity.

To mitigate the risk of impacts on fisheries in Malawi, various strategies may be considered, including further promotion, education and start-up support for entrepreneurism in aquaculture and the encouragement of commercial operators in this sub-sector; sustainable fisheries management, conservation of critical habitats and efforts to address overfishing which must involve local institutional capacity. Adaptation measures such as promoting climate resilient fishing practices and technologies are important for building the resilience of the fisheries sector and fishing communities up and down the country.

f. Infrastructure

Infrastructure risk assessment

Infrastructure development lies at the nexus of economic growth, productive investment, job creation, and poverty reduction. For Malawi infrastructure, especially with regards to communications, (roads, railways, telecommunications), power and water services, has been an Achilles Heel to socio-economic development. Weak infrastructure not only constrains development, it is also a factor of vulnerability and exposure to the ravages of climate change and extreme weather. The challenge for Malawi, with weak economic indicators and a heavy debt burden is to improve infrastructure resilience, strengthen DRR and promote climate resilient infrastructure development in order to assuage the increasing risk of loss and damage faced by Malawi's infrastructure assets.

In terms of power generation, risk is attached to leaving all generating capacity to hydro plants on the Shire River which is projected to experience the impacts of more frequent and intense extreme weather events such as drought and flood. As will be explained in the Adaptation Options report that will accompany this CRA, Malawi can benefit from measures to increase the climate resilience of its electricity infrastructure. Key options include diversifying the locations of hydropower plants, such as replacing the postponed new Songwe which was planned to supply Karonga District and the rest of the Northern Region with electricity with the more resilient Lower Fufu facility on the South Rukuru River in Rumphi District, reducing transmission losses, and increasing regional trade within the Southern Power Pool—which, the World Bank claims, would bring about twice the benefits in terms of additional hydropower generation compared to shifting hydropower which would be a capital intensive option.[143]

With roads, a World Bank report says that climate change impacts could increase the cost of building, operating, and maintaining Malawi's roads and bridges by as much as US$100 million per year during 2036- 2050 relative to historical levels.[144] This can be explained by the density of primary and

[143] https://documents1.worldbank.org/curated/en/099545010272237260/pdf/P1772201ced75ce9182e7142761bde013662bca4fe42.pdf

[144] Ibid

secondary roads in Malawi that are in a very poor condition,[145] which can be contextualised by the observation that only 4038 of Malawi's 15451 km of roads are paved, partly as a result of the attentions of Cyclone Idai in 2019, Tropical Storm Ana in 2022 and Cyclone Freddy in 2023 which caused loss and damage to roads that were never built to withstand the climate change and weather events being experienced now. Excluding the few paved trunk routes, close to 38 percent of the villages in Malawi are not accessible by motorized vehicles in the rainy seasons and only 26 percent of the total population lives within 2 km of an all-weather road.[146] This leaves rural communities at high risk of being cut off when tracks get washed away as happened in 2023 to the densely populated hinterlands to Lake Chilwa in the southeast of Malawi.

Commenté [LP46]: Could you please add reference

Commenté [LF47R46]: Done

Maintenance has been another missing feature of infrastructure management whilst substantial repairs and replacements, for example the 180 m span Chapananga Bridge in Chikwawa District, built at a cost of MwK 8 billion and left derelict after being broken and parts washed away in 2022, require considerable sums to relocate, redesign and construct with stronger resilience. Many bridges are old or are being traversed by traffic far in excess of what they were designed and built for so that main arterial roads are constantly at risk of loss and damage from extreme weather.

In the field of telecommunications, despite having a fairly good national backbone, network infrastructure, usage and penetration are limited due to intermittent or low access to electricity. And this, in turn is affected by climate hazards affecting hydropower generating stations. Most of Malawi's telecommunications is serviced by a network of lines and poles and these are at risk from storms (lightning) and of being washed away by flash floods as a result of increasing extreme storm activity. Cyclone Freddy, in March 2023, wiped out thousands of power pylons, poles and lines: "Information is also being hampered by the lack of electricity resulting from damaged electricity poles and wires. This is affecting internet/network connectivity and subsequent transfer of information."[147]

Commenté [J[48]: It might be useful here to bring an example from Cyclone Freddy

Commenté [LF49R48]: Done

Climate change and extreme weather have significant impacts on infrastructure in Malawi, affecting various sectors such as transportation, energy, water supply and housing. Some of the key impacts are as follows:

1. Rainfall – changing patterns of rainfall can affect infrastructure such as municipal water supply and sewerage installations with potential disruptions to water supplies for vital services and to irrigation infrastructure for agriculture, essential for crop production and for health of livestock.

2. Storms and flooding – Critical infrastructure, including homes, health facilities, schools, roads, railways, ports, bridges, food stores and markets can be degraded and made unusable by the sheer force of severe storms and winds which are projected to increase in the projections produced for this CRA. Flooding in Malawi, especially in the context of projected increasing occurrence of heavy rain events countrywide and cyclonic activity in the Southern Region has an increasing capacity to disrupt infrastructure, especially roads, bridges, cutting off communities from help and relief and preventing access, both to vital supplies and for people to be able to exit areas of danger. Also affected are power installations (Malawi's are nearly all hydroelectric located on the Middle Shire River) that are unable very often to cope with

[145] https://openjicareport.jica.go.jp/pdf/1000004247_02.pdf
[146] World Bank (2021) 'Malawi's infrastructure: A continental perspective,' WB Policy Research Working Paper 5598
[147] https://actalliance.org/wp-content/uploads/2023/03/ACT-Alert-Malawi-Cyclone-Freddy.pdf , see also https://africa.oxfam.org/latest/press-release/100-days-cyclone-freddy-farmers-malawi-and-mozambique-have-nothing-grow-ahead

floodwaters that bring silt and debris that can damage turbines leading to power outages, often for long periods of time, impacting, not only homes but businesses and industry.[148]

Commenté [LP50]: Could you please add reference

Commenté [LF51R50]: Done

3. Rising temperatures and extreme heat – can lead to heat stress on infrastructure, especially roads and bridges which may buckle and break up due to unplanned for expansion and melting. Buildings, such as hospitals and offices may require cooling during heatwaves, increasing energy costs and drain on scarce fuel reserves.

4. Drought and prolonged dry spells – can reduce water availability for hydropower generation upon which Malawi depends for electricity generation, leading to heightened risk of power outages with impacts on all sectors that depend on a reliable power supply.

5. Economic impacts – the cumulative effects of climate and weather impacts on infrastructure can have economic consequences including reduced economic activity and productivity, increased pressure on government and private sector budgets for repairs and maintenance A further cascading risk is of potential reductions in foreign investment which may be deterred by the fragility of infrastructure in Malawi and risk of disruptions.

6. Resilience – As much of Malawi's infrastructure was not designed to withstand the increasing intensity of extreme weather events, this propels increasing further diminution of resilience of sectors that depend on vital infrastructure including agriculture, fisheries, business and infrastructure in public sectors including health and education.

7. Health - climate change impacts on infrastructure can also have cascading impact on health, such as waterborne diseases related to disruptions in water supply and sanitation systems, with 85.3% (2023 estimate, see footnote) of the population using pit-latrines as their toilet facility.149 As these get overwhelmed and destroyed, people have no alternative but to turn to open defecation raising the risk of increased disease and burdens on fragile health infrastructure. Health services are also put at risk when power outages occur at hospitals and clinics rendering such infrastructure reliant on expensive and complex generators for which fuel may not be available due to damage to transportation infrastructure.

8. Education – schools and colleges currently have to double up as relief centres and temporary camps for displaced families from storms such as Ana and Freddy, but this school infrastructure was not constructed for that purpose and is ill-equipped for use as emergency shelters. In addition, school activities have to cease while waiting for displaced people to be able to return to their homes. Many schools in rural areas are themselves constructed with weak materials or are old and suffer considerable damage from flash floods and other storm damage. The following evidence was gathered in March 2023:

Commenté [LP52]: Could you please add dates/ more context, for the report to remain relevant in the future?

Commenté [LF53R52]: Done

> *In Malawi more than 490,000 primary and secondary school aged children – about 5% of children - are unable to attend school due to the damage caused by Cyclone Freddy, Save the Children said, with many schools likely to be closed for the next four weeks at least.*

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[148] Damage to power infrastructure – Cyclone Ana 2022: https://www.africanews.com/2022/02/07/malawi-to-experience-six-month-power-outages-following-deadly-storm// also https://www.voanews.com/a/malawi-loses-30-of-its-electricity-to-tropical-storm-ana-/6429686.html and Cyclone Freddy 2023: https://www.bbc.co.uk/news/world-africa-64938811

[149] Hinton, R.G.K. et al (2023) 'The Status of Sanitation in Malawi: Is SDG6.2 Achievable?' *International Journal of Environmental Research and Public Health*. 5, 20, 15 accessible at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10418781/#:~:text=Pit%2Dlatrines%20remain%20the%20primary,their%20toilet%20facility%20%5B19%5D.

The government has closed all schools in the affected southern districts, as classrooms and toilets have been deemed unsafe as the result of heavy rains, floods and landslides, following Cyclone Freddy, which made landfall in Malawi on 11 March.

About 230 schools which withstood the cyclone are now being used as temporary accommodation for some of the 362,000 people who have been displaced. Roads also need to be cleared so children can safely travel to school. Schools were due to open on 20 March, but this wasn't feasible, so the re-opening of schools is now scheduled for four weeks later on 17 April. This comes on top of school closures at the start of the year as a result of a cholera outbreak.

Jane from Mulanje district is in Grade 8. She was due to sit for her final exams on 10 May, but without the vital books and infrastructure, it looks unlikely. Jane said: "A lot of people died here, including a lot of pupils from the school. Ours was a really good school but now all the property and books are gone. These exams will be difficult and it makes it difficult for some of us to pursue our dreams."

Almost 140,000 children are directly impacted by the floods, with many now living in camps. More funding is urgently needed for the humanitarian response, including education.
"I think that they are reflecting on the events and thinking of the problems back home, as some of them lost everything. And even some of them are here in the camp, where the situation is really not that good, as they sleep on the floor and there is no privacy, "he said. Teacher houses were turned into evacuation camps, hosting some of the flood survivors and sharing their hygiene facilities.[150][151]

The second of these two reports highlights the psychological stress suffered by schoolchildren as a result of these exigencies suffered as a result of the ravages of Cyclone Freddy, with loss of books, exam papers and materials as well as loss and damage to their schools and being taken over by displaced peoples, a perhaps under-rated impact of inadequate infrastructure.

Risk summary (infrastructure

As fragile infrastructure comes under increased pressure to withstand projected changes in climate and extreme weather, so too does pressure on financial and technical resources to pay for repairs and maintenance of infrastructure (such as roads, bridges and public buildings), straining government budgets. Current infrastructure in Malawi is at high risk of loss and damage from climate change and extreme weather. Infrastructure that is damaged by storms rarely gets adequately rehabilitated before the next round of storms arrive. This is particularly a problem in the Southern Region and in the vast informal settlements in urban areas. Some new roads of high resilience are being constructed around Lilongwe but the vast majority of the road network is of low resilience and is already degraded and damaged even before extreme weather strikes.[152] The routes that these roads take, like the 797km narrow gauge railway system that was constructed in the first decade of the 20th century, together with their bridges, have become vulnerable to flood damage and without substantial work to re-route and renew this type of infrastructure is at high risk of frequent substantial damage.

To address these challenges, adaptation should consist of strengthening existing infrastructure and improving infrastructure resilience, strengthening DRR measures and promoting climate resilient

[150] https://reliefweb.int/report/malawi/nearly-half-million-children-malawi-unable-attend-school-due-cyclone-freddy
[151] https://commonwealtheducationtrust.org/cyclone-freddy-and-education-in-malawi-part-2/
[152] https://irap.org/2022/07/malawi-commits-to-safer-roads-by-2030/#:~:text=Poor%20road%20infrastructure%20and%20driver,50%25%20by%20the%20year%202030.

infrastructure development.[153] International cooperation and support for these efforts, including financial assistance and technology transfer are likely to be essential to help Malawi to adapt to the changing climate and likelihood of increased occurrence of extreme weather and protect its infrastructure.

Commenté [LP54]: Are the paragraphs proposing solutions based on the district level consultations? It would be good to mention what's the source of the recommendations

Commenté [LF55R54]: Please see footnote

g. Tourism-wildlife

Tourism is an important potential growth area in many Sub-Saharan African countries, and Malawi is no exception, branding itself the 'warm heart of Africa' denoting its friendliness and welcoming nature to foreign tourists. The Malawi Vision 2063 document targets a 100% increase in tourism in terms of its contribution to GDP, from 7-7% in 2018 to 14.4% by 2040 and 20% by 2063 (GoM 2020).[154] Concomitantly, according to the AfDB (2017), compared to other countries in the Southern Africa region, Malawi lags behind in tourism receipts and tourism-supporting infrastructure, ranking 10th out of 14 countries in tourism arrivals.[155] The National Tourism Investment Master Plan 2022–2042, launched in April 2022, identifies Malawi's lakes and nature and wildlife as its top tourist attractions.[156] These natural features have been seen in this study to face increasing risk of loss and damage from climate change and extreme weather in Malawi.

As has been presented in the climatology section of this CRA report, Malawi, along with other countries in Southern Africa, has been experiencing increasingly variable and unpredictable climate and weather patterns, including extreme weather events such as droughts, cyclones and heat waves. Drought, in particular leads to die-back and even extinction of many wildlife species.[157]. This has longer term implications for the survival of different species of flora and fauna that have thrived on climate conditions in the past. Some of the starkest risks of extinction apply to large herbivores such as elephants and hippopotamuses which are especially vulnerable to climate change due to their reliance on large quantities of grass and other types of vegetation for food intake. Climate related variation and extremes, couples with increasing encroachment of humans on wildlife habitats have direct implications for the abundance and distribution of wildlife resources such as water and vegetation. Understanding the influence of these vectors of change is vital for the development of strategies aimed at conservation and adaptive management.

Climate change could undermine those assets and exacerbate biodiversity loss and land degradation. More frequent and more intense extreme events could also damage tourism infrastructure, especially

[153] It should be noted that recommendations that appear here and in the following Adaptation Options Report are all extrapolated from the expressions of District stakeholders in evidence given either at the field workshops or during consultations on field visits to communities undertaken as part of this work in July/August 2023.

[154] Government of Malawi (2020) 'Malawi 2063: Malawi's vision – An inclusively wealthy and self-reliant nation,' National Planning Commission, Lilongwe.

[155] https://copenhagenconsensus.com/publication/malawi-priorities-transport#:~:text=Tourism%20contributes%207.7%25%20to%20Malawi's,is%20an%20opportunity%20for%20growth.

[156] https://documents1.worldbank.org/curated/en/099545010272237260/pdf/P1772201ced75ce9182e7142761bde013662bca4fe42.pdf

[157] https://www.intechopen.com/chapters/56873

transport and communications infrastructure such as roads, which are important for tourism in order to gain access to reserves such as Nyika, Kasungu and Lengwe National Parks which lie, in part at least, in Rumphi, Kasungu and Chikwawa Districts (focal districts for this study) respectively. Roads to these parks are vital links in the tourism sector value chain and all the national parks marked on the accompanying map (Figure 31) require substantial journeys by road and that the road network is already weak and suffering as a result of the ravages of repeated extreme tropical storms – most recently Ana and Gombe (2022) and Freddy (2023) during which, over 5000 km of roads were destroyed.[158]

Meanwhile, for wildlife, all four of the climate hazards prioritised for this study, affect wildlife. Storms tear down habitats and kill wildlife, floods wash away and leave survivors helpless, excess heat kills and exacerbates the disease burden, drought, as a slow-onset event is an insidious creeping risk to wildlife as it deprives them of food and water and causes them to stray out of protected areas and into direct conflict with human populations eking an existence through smallholder farming or, in the case of Chikwawa, straying into commercial farming (sugar plantations) where they may be shot). Recent literature on this issue is sparse. Mkanda (1996 and 1999) renowned work on climate predictions and potential impacts on wildlife,[159] were referred to in the compilation of the Malawi NAPA Wildlife Sector Report (2006),[160] while a December 2023 report by IFAW outlines some of the pressing challenges facing wildlife in the case of deepening ENSO events across Africa.[161]

Figure 31: Map showing location of Malawi's national parks, all requiring substantial road journeys from the country's international airport at Lilongwe

Risk summary (wildlife)

Climate change and extreme weather combine with human intrusion of habitats to threaten the sustainability of natural ecosystems upon which wildlife depends for survival. When the ecosystem

[158] https://www.tearfund.org/stories/2023/03/what-does-response-look-like-after-cyclone-freddy

[159] Mkanda, F.X. (1996) 'Potential impacts of future climate change on nyala Tragelaphus angasi in Lengwe National Park, Malawi,' *Climate Research*, 6: 157-164 and Mkanda, F.X. (1999) 'Drought as an analogue climate change scenario for prediction of potential impacts on Malawi's wildlife habitats,' *Climate Research*, 12: 215–222

[160] https://unfccc.int/resource/docs/napa/mwi01.pdf

[161] https://www.ifaw.org/uk/journal/el-nino-impacts-wildlife-africa-nature-based-solutions

balance gets disturbed, wildlife may become less abundant and risk being destroyed from straying beyond failing habitats into areas occupied by humans for agriculture or built communities. Wildlife brings benefits to local and national economies through by attracting tourists whilst responsible tourism that features the conservation of wildlife also adds to the preservation of biodiversity, a valuable adaptation measure. However, tourism is a fragile and highly vulnerable economic sector in which losses and disinvestment can occur very qasily and quickly when attractions such as wildlife and the supporting infrastructure such as good quality roads and accommodation become degraded as a result of not being resilient enough or by suffering damage from storms, drought and excessive heat.

h. Water

Water risk assessment

The water budget In Malawi is correlated with rainfall. temperature and evaporation/evapotranspiration. One factor that needs to be born in mind is that water from rainfall falling on the surface of water bodies in a sub-tropical environment is likely to be cancelled out by evaporation. For example, it was estimated in 1983 that mean annual precipitation over the surface of Lake Malawi amounted to 1350 mm per annum while evaporation amounted to 1610 mm.[162] As atmospheric and water temperatures have increased since then this proportionality in favour of evaporation is unlikely to have reduced. Therefore, water availability from rainfall depends more on run-off. The map in Figure 32 shows surface run-off per annum in mm. Most run-off in Malawi occurs across the surface with little replenishment of the water table except in the central west. Potential for irrigation zones are shown with red hatching. Flash flooding, which occurs especially from the highland areas of Viphya, Nyika, Zomba and Mulanje, does not result in water retention (darkest shaded areas of map),[163] therefore considerable attention might be concentrated on water harvesting addressed in the Adaptation Options report accompanying this document.

Following the discussion above under Climate , it has been posited here that removal of forests, combined with an increase in atmospheric and surface temperatures and a more variable rainfall pattern leads, inexorably, to an increase in evaporation over water bodies such as lakes, threatening supplies of water to the power infrastructure on the Shire River, and a decrease in water recycling over land, leading to increasing drying of soils and less feedback of water vapour to the atmosphere, therefore potentially reducing rainfall, apart from what is brought in by the cyclonic inputs from the southern Indian Ocean and the ITCZ/CAB. In effect, this translates as intensification of drought and Mtilatila (2020) asserts that this will be most pronounced in the north and centre of the country while this report suggests the effect will be countrywide.

[162] GoM (1983) National Atlas of Malawi, Department of Surveys, Blantyre, Malawi, 79 pp.
[163] Ibid.

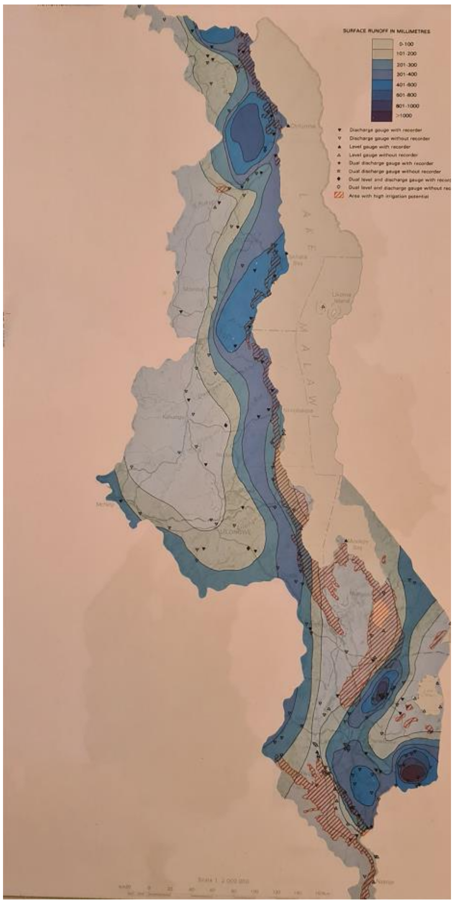


Figure 32: surface run-off throughout Malawi in mm. Darkest shading indicates highest run-off from steep slopes and escarpments where flash flooding is the norm during the rainy season. Red hatching indicates zones of potential irrigation mainly along the southern Lake coastal strip including Salima District and parts of Dedza and the Shire River Basin including Chikwawa District; whereas in the lighter coloured zones such as Central Region west, including Kasungu District, run-off is less intense but infiltration is higher (GoM 1983).

This latter decrease in the water budget over the land and reduced soil moisture risks agricultural crop production and livestock sustainability, and water for life – drinking, cooking, washing, sanitation, urban reticulation. Those districts such as Kasungu and Rumphi where agriculture represents the highest proportion of productive activity and contributions to food security and exports (tobacco) may suffer badly in this scenario while the south, in districts such as Chikwawa and Nsanje may find that, apart from commercial sugar plantations, which are irrigated from the perennial flow of the Shire River, there will be heightened water insecurity and crisis affecting the densest concentrations of population.

The provision and assurance of sufficient water in households, especially in rural Malawi, generally falls to women who, in the face of a drying climate or where water sources have been polluted by floodwater, have to walk great distances, often at personal danger to themselves. Part of the risk element attached to water is that the search for sufficient potable or clean fresh water, casts further

Commenté [LP56]: Would it be possible to have a map summarising the water security changes across districts? I'm thinking it's the kind of "easy to grasp" elements that will be useful in the policy brief as well

Commenté [LF57R56]: Have done what I can here. I think the run-off map is very revealing. These maps, rather like geomorphological ones, do not go out of date.

burdens on a section of the community that provides and manages coping strategies in the household (see next subsection on gender).164

Climate change and extreme weather have significant impacts on water resources in Malawi, affecting the availability, access, distribution and quality of water. Dry weather, increasing temperature and heat extremes all affect water security. Given the country's heavy reliance on hydro-power and rain-fed agriculture, the cascading effects on a range of sectors are profound. Some of the key impacts are as follows:

1. Changes in rainfall patterns – including irregular heavy rain often followed by dry periods affect water harvesting, availability and quality.
2. Floods – both pluvial and fluvial, that inundate fertilised farmland and polluted urban areas, impact freshwater availability and supply and risk contamination. Flooding can also displace communities leading to social and economic disruptions.
3. Dry spells and droughts, intensified by higher temperatures risk water scarcity for agriculture, power generation and household use.
4. Extreme heat – negatively affects water quality and enhances rates of evaporation and evapotranspiration.
5. Health – good health depends on an adequate supply of clean fresh water, not only for drinking, cooking, livestock etc. but also for sanitation.
6. Biodiversity and ecosystem integrity – changes in water availability can affect both aquatic and terrestrial ecosystems, changing their balance and threatening the biodiversity they support as well as the human security nested into those systems.

Risk summary (water)

Climate change and extreme weather jeopardises water supply challenges specifically the reliability and sustainability of water supply systems. Enhanced evaporation induced by increasing temperatures, direct sunlight and lack of rainfall risk diminishing levels and volumes of water in lakes and other bodies risking water availability for lives and livelihoods and supplies of water to power stations threatening power supplies to the country which depend almost wholly on hydroelectric generation. Diminished soil moisture, as a result of broken and diminishing rainfall patterns and enhanced evaporation exacerbated by deforestation, and water from surface water bodies for irrigation impact agriculture – crop production and livestock – threatening already inadequate food supplies and sharp price rises, risking food and health security which can only be solved by importing food from outside at great cost – if it is available.

Commenté [LP58]: It's great to have a risk summary for each section thank you

Commenté [LF59R58]: Sure

Commenté [LP60]: Is there a word missing?

Commenté [LF61R60]: Change of wording

i. Health

Health risk assessment

Malawi's long history of weather-related disasters is also associated with poor health services and health-related outcomes. For example, following the 2015 floods that affected 1,150,000 people, displaced 336,000, and killed 104 (GoM 2015a), the country experienced a surge in cases of malaria (23.1%), eye infection (8%), skin infection (39.9%), acute respiratory infection (19.9%), and diarrhoea (18.2%), compared to a baseline year of 2013-2014 (GoM 2016). In addition, the floods damaged

164 https://www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf

health facilities, available medical supplies failed to meet increased demand, and affected areas recorded high health worker absenteeism as staff homes were affected (World Bank 2015; GoM 2019b). In Nsanje District adjacent to Chikwawa District, which has an HIV prevalence of about 16% among the adult population, people lost their health passports in the 2015 floods, facilities experienced HIV drug stockouts, and many patients were out of treatment for up to two weeks (UNDRR 2015).

The disease burden in Malawi is likely to increase as a result of climate change. Diseases such as cholera and other waterborne diseases that occur due to dirty water and poor hygiene and accelerate every time there is a flood event in Malawi are likely to increase along with the predicted increase in heavy rain and flooding. Scabies, another highly contagious disease, linked to climate change, resulting from poor hygiene linked to lack of fresh clean water. It is significant that an outbreak of scabies was reported as occurring in October 2023 over 8 months after the cyclone struck and was being indirectly linked to it.165

The risks attached to malaria and other diseases linked to the mosquito, are likely to increase in intensity wherever there is standing water which will increase with more heavy rainfall and flooding. In addition, as atmospheric temperatures increase, malaria will also become more prevalent in mountainous areas of the country such as the Nyika Plateau, Shire and Zomba highlands and the Mulanje Massif, which have not been highly affected to date because of hitherto cooler temperatures.

Other indirect health outcomes increase the risk to populations in Malawi, especially those communities worst hit. Referring to the health outcomes of Cyclone Freddy, it was reported that 'Health campaigners believe the outbreak (cholera) could be directly linked to the climate crisis, as the current heatwave, high humidity and water shortages across Malawi make people more vulnerable to disease outbreaks.'

Climate hazards pose significant risks to human health. These can be direct or indirect depending on the particular type of hazard and the state of vulnerability of the affected population. Some of the key risks associated with health in Malawi include:

1. Storms – can result in loss and damage to weakly constructed health posts and hospitals resulting in loss and damage to equipment, beds and medications. Flying debris and collapsing structures can cause death and injuries while the trauma of experiencing a climate induced disaster can leave people traumatised, leading to mental health problems, including post-traumatic stress disorder (PTSD), something where there are very few if any facilities to care for across Malawi.

2. Flooding - can lead to being swept away and drowned or injured. Inundation of weak housing can collapse on occupants sheltering inside. Waterborne diseases such as dysentery, typhoid fever and cholera can be spread by contaminated floodwaters. Malaria is endemic throughout Malawi and may experience surges in cases due to standing water resulting from flooding. Flooding of houses and medical posts can lead to loss and destruction of drugs and equipment such as wheelchairs. Those with chronic conditions like HIV can be negatively impacted very quickly as a result of loss of drugs and roads being cut preventing new supplies from arriving.

165 https://www.theguardian.com/global-development/2023/oct/30/malawi-battles-outbreak-of-scabies-that-health-experts-link-to-climate-crisis

3. Extreme heat – heat related illnesses; prolonged exposure to extreme heat can lead to heat exhaustion and heatstroke and can exacerbate cardiovascular conditions and increase the risk of heart attacks and strokes.

4. Drought – may lead to water scarcity, affecting human health through imposed constraints in hygiene and sanitation, increasing the risk of waterborne diseases. Crop failures due to drought may impact on food security through crop failures. Loss of livestock and decimation of the fisheries. This can lead not only to hunger but also to stunting of children.

5. Wildfires – can lead to respiratory problems as smoke contains fine particles; asthma and other lung diseases can be exacerbated as can cardiovascular issues – smoke exposure can be linked to increased risk of heart attack and stroke.

6. Vector-borne diseases – changes in temperature and rainfall can affect the distribution of mosquitoes and ticks that spread malaria, dengue fever and Lyme disease. Malawi is also vulnerable to diseases like lymphatic filariasis and schistosomiasis which are serious health problems throughout Malawi, especially in the South but are poorly recorded or documented, can be influenced by climate hazards.

7. Food security - health issues including malnutrition and consequent conditions can be catalysed by heat extremes, drought, storm and flood.

8. Displacement – can occur from flooding, loss of homes, and drought when farms – crops and livestock are lost or washed away. Displacement may result in pressures being put on emergency shelters such as schools that have to close for education and which are not designed to be able to cope with influxes of people who have lost their homes and possessions and where conditions may result in high vulnerability to infectious diseases and to mistreatment, particularly of women and girls.

9. Mental health – a range of mental health problems can ensue from exposure to extreme weather events, especially when people experience shocks they have not imagined before and where they lose homes, livelihoods and/or family members. These impacts can be long-lasting having negative cascading impacts on personal and family development and the national social economy. This risk factor is exacerbated by the fact that there are very few practising psychiatrists and psychologists in the country and because mental illness is seen by many, including in governance, as a condition for the wealthy to address.166

Risk summary – (health)

The health risk factor is greatest for the most vulnerable groups such as the very poor, very young, the elderly, and those with pre-existing poor health. Women and girls, the disabled and other marginalised groups are among those groups at highest risk. Health impacts can be divided between death and injury which are immediate impacts and disease which is a medium to longer term impact with

166 During the course of field research for this CRA (late July 2023), the CRA Team Leader visited the Ndi Moyo Palliative Care centre in Salima, founded by a Malawian nurse, the only establishment of its kind in the country which exists by virtue of donations only to care not only for the terminally ill but for the sick and disabled who have lost hope. Such a service is valuable contribution to recovery and rehabilitation for people who are unable to cope with suffering. Unfortunately, the future of this centre is severely challenged by lack of funds and lack of support from within the country. A visit to the Ndi Loyo website can explain more about his centre – https://www.ndimoyo.org/

implications for productivity and social and economic wellbeing. Efforts to address these health risks in Malawi may involve improved disaster preparedness and response, investments in better healthcare infrastructure, more disease surveillance and public health campaigns to educate all sectors of the population about the health risks attached to climate hazards. In addition, adaptive measures to enhance resilience to climate change, such as enhanced water resource management and sustainable agriculture and fisheries can help mitigate some of these risks.

j. Gender considerations

Climate change and extreme weather events have distinct impacts on women and girls and gender relations in Malawi. Women often face disproportionate vulnerabilities and impacts and challenges in relation to climate and weather and this has much to do with their roles and responsibilities and unequal status in their communities. This inequity exists on a sliding scale from the big urban areas where modernity and associative values shape roles and gendered relations to remote rural areas where gender differentials are likely to be most marked by traditional communitarian values. Particularly in rural areas, gender inequality is reinforced by social norms.[167] Climate change and extreme weather affects women and girls most acutely partly because of the aforementioned gendered roles in society but also because it entrenches and exacerbates existing gender inequalities. 168 As was mentioned earlier, while 80% of the economically active population are involved in agriculture, 59% women and 41% men,169 and while women play an important role in the sector constituting 70% of full-time farmers, carrying out 70% of the agricultural work, and producing more than 80% of subsistence crops. Indeed, it has been postulated that women play a key role in agriculture in Malawi, producing 70% of food that is consumed locally[170] yet only 32% of agricultural landholders are women,[171] suggesting a gender imbalance towards land ownership and tenure. Impacts on women and girls are disproportionately burdensome because climate and weather are so closely aligned with traditional female roles in society, especially rural society such as farming, small business, cooking, washing, fetching water, nursing, reproduction of the family, both physically and in terms of education and installation of culture and values. Meanwhile, those women and girls who are forced by the scale of impacts to seek other opportunities outside of their traditional roles, find it difficult to enter male dominated employment avenues, increasing the burdensome impacts still further.[172]

Some of the pressing impacts on women and gender relations are as follows:

1. Increased workloads: women in Malawi (as elsewhere in Sub-Saharan Africa) are typically responsible for household tasks, including water collection, cooking and childcare. Climate change and extreme weather can exacerbate the burden of these tasks, both during floods

[167] https://www.futureclimateafrica.org/wp-content/uploads/2017/04/gender-agriculture-climate-services-brief-umfula-final.pdf
[168] https://www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf
[169] https://malawi.unfpa.org/sites/default/files/resource-pdf/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report%20%281%29.pdf
[170] FAO SOFA 2010-11, Women in Agriculture –closing the gender gap. http://www.fao.org/publications/sofa/2010-11/en/ also https://www.futureclimateafrica.org/wp-content/uploads/2017/04/gender-agriculture-climate-services-brief-umfula-final.pdf as part of Kulima research in Malawi
[171] https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA%20_Profile_Malawi.pdf
[172] https://www.actionaid.org.uk/our-work/emergencies-disasters-humanitarian-response/climate-change-and-gender

Commenté [gm62]: Is this the case for Malawi? good to back this with stats

Commenté [LF63R62]: Yes, I have extrapolated the theory in the text. It is not just my theory but rather a standard component of the gender and development (GAD) theoretical paradigm, an approach that focuses on the socially constructed differences between men and women, the need to challenge existing gender roles and relations, and the creation and effects of class differences on development. The notion of a sliding scale in which most gender inequality exists in more communitarian societies is a standard tenet in WID, WAD GAD and neo-liberal gender approaches. At our field mission meetings, women present confirmed that their female relatives who had moved to cities like Lilongwe and Blantyre had more access to equal roles in the household due to their improved access to trading and ability to get waged jobs and with higher access to global media. I do not have Malawi stats to hand on this but stand by the argument based both on research and empirical evidence from the field mission.

Commenté [gm64]: Please verify this beyond the world report, this may be a misrepresentation,

Commenté [LF65R64]: Various writers and reports produce the same logic with slightly varying figures. I think it is important not to play down the hidden productivity and work of women, especially in agriculture in Malawi, whilst their plots are on average smaller than those of men, and they suffer, thru gender inequalities less access to ownership and decision making, finance, new knowledge and technological skill transfers. If the reviewer believes this to be a misrepresentation, then it would be useful to see the counter-argument evidence so that we can weigh this against the evidence supplied here and then make appropriate amendments/deletions.

Commenté [LP66]: if there are no references it would be better to remain factual

Commenté [LF67R66]: There are references tho if more are sought, it would be helpful to see which portions of text are referred to and these will be provided. Sometimes in these reports, we speak from personal knowledge and experience and the evidence of respondents during the field mission. If we had the time and resources, we could produce a dedicated paper on the issue of gender, climate and the development deficit in Malawi. We look to be factual throughout..

and droughts, when women have to walk increasingly longer distances in search of usable water whilst also having to provide supplementary care for family members affected by food, fuel, water and medicine scarcity. Such resources become scarce during times of crisis with increased competition placing further challenges on women especially those who are female heads of households with few rights.

2. Health risks – women are often the primary care givers in households, including for young children, the sick and the elderly Increasing climate and weather-related diseases and poor health including injuries, waterborne diseases and heat-related illnesses can increase the burden on women and girls and affect their own health and wellbeing.[173]

Commenté [gm68]: Suggest separating care burden placed on women and actual health risks.

Commenté [LF69R68]: The point here is that there is a direct connection. Because women and girls tend to be the primary providers of medical care in the household - this exposes them to increased risk of disease (for example cholera - a climate exacerbated health condition) and ill health and fatigue which is exacerbated by extra burdens imposed by climate and weather related impacts on care. See the footnote.

3. Food security – As previously noted, climate change and extreme weather can lead to reduced agricultural productivity which impacts household/family food security and nutrition, a responsibility of women and girls who bear the brunt of these challenges when food becomes scarce and prices exorbitant, especially when roads become impassable or crops washed out.

4. Education – girls' access to education can be disrupted by climate and weather impacts. They will be the first to be fetched out of school to stay at home to carry out household tasks and family relief when disaster strikes. There is an ongoing imbalance in Malawi between girls and boys going on to and remaining in secondary (26% of pupils not in school in Malawi in 2018 compared to 18% boys),[174] and tertiary education with the pendulum swinging firmly in favour of boys. Opportunities for advancement for girls then becomes limited (see Figure 31). As climate disaster strikes, so these inequalities are exposed in unequal impacts.

Commenté [gm70]: As much as possible refer to statistics. Reports on the floods in the south and on general education outcomes EMIS has data

Commenté [LF71R70]: See amended entry, footnotes and extra figure

5. Gender-based violence – girls and women also become vulnerable to violence both within the home when the household is suffering multiple exigencies and in temporary shelters where insufficient separation and privacy is provided in sleeping accommodation and toilets.[175] As providers, especially in female headed households, loss of income, for example when crops get destroyed due to climate hazards, lead to women defaulting to transactional sex as the only way of putting food on the table tho this practice comes with considerable risks of violence and health problems to women themselves.[176] A further vulnerability faced by girls is the possibility that they will be married off at a young age in a short-term attempt by parents to make short-term gains and reduce the number of family members to feed and look after.[177] This practice also stunts girls' chances of advancing in education and they can get rapidly

[173] https://www.climatecentre.org/wp-content/uploads/RCRC_IFRC-Country-assessments-Malawi_Final3.pdf esp. p.9, also https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6038986/ for a more global view.
[174] Malawi National Gender Statistics Assessment (2022) UN Women in Malawi found online at https://data.unwomen.org/sites/default/files/documents/Publications/Assessment%20of%20Malawi%20National%20Gender%20Statistics%20System.pdf which quotes statistics from the Malawi National Education Profile 2018
[175] https://www.ohchr.org/en/stories/2022/07/climate-change-exacerbates-violence-against-women-and-girls
[176] https://www.theguardian.com/global-development/2023/dec/14/malawi-prostitution-rural-women-forced-to-sell-sex-after-cyclone-freddy-destroys-crops-resilience
[177] https://www.globalcitizen.org/en/content/climate-change-is-creating-more-child-brides-repor/#:~:text=In%20Malawi%2C%20one%20of%20the,by%20the%20European%20Journalism%20Centre. , https://www.aljazeera.com/features/2020/2/19/marriage-of-survival-will-climate-change-mean-more-child-brides , https://www.tandfonline.com/doi/full/10.1080/17441692.2022.2095655

weighed down by domestic burden and early childbirth, endangering their health still further.[178]

6. Participation in decision making – women, as multi-tasking managers, face unequal struggles when it comes to expressing the problems facing impacted communities, even though they are best placed to explain to outsiders with resources how to make interventions to support communities affected by weather and climate actually work. Women are prime knowledge holders and possess knowledge capital (the day-to-day ability to make informed decisions that protect whole families and communities from worse impacts). Women's participation in decision-making is essential for effective climate change adaptation. Yet, women may find it disproportionately hard to access information on early warning systems, forecasting and plan for the likely impacts.[179] Lower education opportunities exacerbate this problem. The ongoing risk is that, without statutory intervention, and perhaps even with it, because societies are under pressure with multiple stressors including climate change, women will continue to be externalised from involvement in these processes. Their ability to participate in this kind of decision making may continue to be thwarted.

7. Access to knowledge- related to 6 above, women's access to knowledge is often constrained by lower education opportunities and lack of access to information and knowledge. This makes it difficult for them to prepare themselves and their families for catastrophe when it strikes and to be able to support recovery and rehabilitation.180

8. Economic impact – as already noted above, women are often engaged in small-scale business such as cooking and catering, and trading including of any surplus agricultural produce. Climate change can and does thwart their economic opportunities by diverting their priorities from income generation to relief and emergency care, limiting their ability to generate income that helps support and benefit whole families. Failure to recognise and capacitate the potential that these groups harbour represents an economic loss to whole communities.

[178] Evidence to support this is provided in the narrative reports from every district during the field mission dedicated to this work which is also referred to in the District CRA reports in the annexes to this report

[179] https://wedo.org/wp-content/uploads/ClimateConnectionsBookletEnglish.pdf , https://www.adaptation-undp.org/gender-climate-information-and-early-warning-systems-africa

[180] When conducting field workshops for this CRA, every attempt in design and planning was made to elicit at least 50% female participation, especially as smallholder farming is conducted primarily by women and requests were sent out for that to the 8 Districts concerned. Unfortunately, the female participation rate for the whole series came out at just 35% although these made a huge contribution to the proceedings. Sometimes the explanations are not obvious; many women encountered during the field mission spoke of lack of confidence to participate and speak out, which is also a legacy of unequal gender relations and a factor of vulnerability in itself.

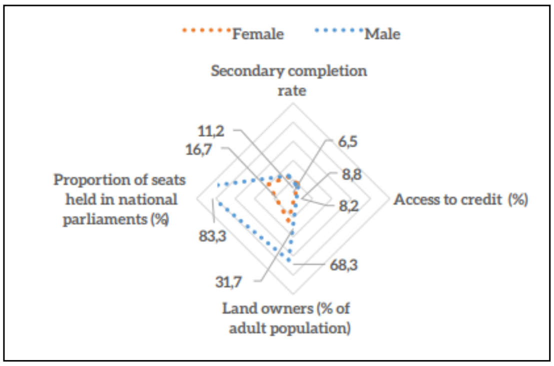


Figure 33: Infographic showing the unequal secondary educational completion, access to credit, land ownership and access to national decision making experienced by women in Malawi AfDB (2020) 'Malawi Country Gender Profile: Current State of Gender equality and Women Empowerment,' African Development Bank.

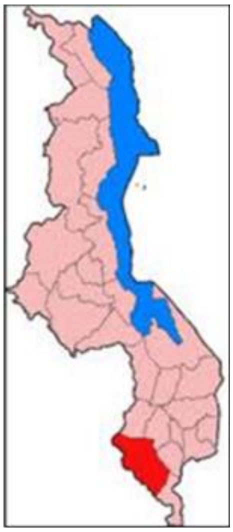
Risk summary (gender)

Climate risk is heightened by insufficient knowledge or poor knowledge management of the hazards and how and when they will strike, and poor communications skills. Gender inequalities, for whatever reasons they exist, are expressed partly through knowledge deficits and lack of understanding, and partly through lack of deployment and exploitation of the vast knowledge and skills cultivated by women and other marginalised groups. These inequalities are reinforced by the impacts of climate change and extreme weather because such impacts affect the poorest in society which women and marginalised people usually are and because the roles in lives and livelihoods most affected are those undertaken predominantly by women and girls. And yet, these are the very same people who have most knowledge of how to cope and what may work in terms of adaptation. The risk is that this imbalance continues to be paid lip service to and that increasing frequency and intensity of climate and extreme weather events exact further tolls on the social ecological systems in play in Malawi without identifying and enabling deployment and exploitation of the vast knowledge and skills reservoir existent in these marginalised groups, which is an adaptation strategy in itself. If women are excluded from the National Adaptation Plan process, this would constitute a further risk component on account of their untapped practical skills in developing management and coping strategies and potential to contribute to adaptation and wellbeing for whole communities.

Efforts to address these gender-specific risks in Malawi include promoting women's empowerment, strengthening their roles in community decision-making and providing access to resources and information. Gender sensitive policies and interventions are essential for building resilience of whole communities and addressing the differential impacts of climate change on women and girls and other marginalised groups such as the disabled.

Annex 1: Chikwawa District – Climate Risk Assessment Report

1. Introduction



Chikwawa district, situated in southern Malawi, shares its borders with Mwanza district to the north, Blantyre to the northeast, Thyolo to the east, Nsanje to the south, and Mozambique to the west. Encompassing an area spanning 4,898 km^2, this district accommodates a population density of roughly 128.8 individuals per km^2.[181] The main economic activities in Chikwawa are agriculture, livestock production, fishing, small scale trade and tourism. Notably, more than 80% of Chikwawa's populace relies heavily on subsistence farming as their primary means of sustenance. However, a striking concern arises as the district grapples with a poverty rate of 62.2%, surpassing the national average of 50.7%.[182]

Chikwawa's climate, characterized as subtropical, moves in a pattern that delineates a rainy season spanning from November to April, while the remainder of the year is marked by a prolonged dry spell. An average annual rainfall of approximately 839 mm defines the norm (average annual rainfall 1991-2020, (DCCMS 2023)),[183] but the district contends with notable interannual variability. This variation in climate imposes formidable challenges, with severe droughts periodically afflicting the region, sometimes yielding rainfall as insufficient as 170 mm during drought years. Conversely, Chikwawa is not spared from the extremities of intense storms, floods, and unusually wet years, where rainfall surges beyond 1,200 mm. These climatic adversities cast a looming shadow over agricultural production and food security, particularly for the predominantly rural populace. For instance, the Chikwawa district grappled with the aftermath of severe flooding in 2019 (from Cyclone Idai), resulting in widespread devastation to crops and infrastructure, displacing over 50,000 residents from their homes. In 2020, floods once again afflicted numerous households. Conversely, the 2015-16 El Niño event ushered in extreme drought conditions, characterized by rainfall deficits ranging from 40% to 60% below the average, prompting emergency relief measures for 64,000 households. Furthermore, the 2019-20 rainy season bore witness to a prolonged dry spell, causing maize crop losses exceeding 60% in certain areas of Chikwawa. Beyond the pendulum swing between droughts and floods, the district experienced the wrath of Tropical Storm Ana in January 2022, which unleashed potent winds and heavy rainfall, aggravating the pre-existing flood-related damage and destruction. These climatic shocks reverberate through the district's economy and the livelihoods of its residents, rendering them exceedingly vulnerable to such events.

Chikwawa's abundant natural resources, including forests, wildlife reserves, rivers, wetlands, and arable lands, represent an invaluable asset. However, these resources are under duress, besieged by

Commenté [LP72]: it would be good to have a map added for each district

Commenté [LP73]: And could we have a risk summary for this case study, like you've done for Phalombe and in the other sections of the CRA report?

Commenté [lf74R73]: Done

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[181] https://www.citypopulation.de/en/malawi/admin/southern/MW310__chikwawa/

[182] https://malawi.un.org/sites/default/files/2022-05/IPC%20Malawi%20Chronic%20Food%20Insecurity%20Snapshot%20-%20May%202022.pdf

[183] DCCMS (2023) Climate Projections for the Eight Agricultural Development Divisions in Malawi, Department of Climate Change and Meteorology (DCCMS), Blantyre.

unsustainable practices, deforestation, and shifts in the environment. Striking a harmonious equilibrium between natural resource conservation and economic development remains an ongoing and formidable challenge for the district.

2. Chikwawa Climate Risk Assessment (CRA)

Chikwawa District experiences various hazards, with tropical storms ranking among the primary threats. In addition, the district grapples with floods and extreme heat events, all of which exert significant impacts on the vital sectors responsible for the community's livelihoods. By examining the consequences of these hazards, we can understand the risks they pose to the community and its socio-economic well-being.

a. Storms

Storms in Chikwawa District are characterized by heavy rainfall and destructive winds, culminating in extensive flooding, substantial agricultural losses, loss of life, damage to residential and infrastructural assets, and contamination of water sources.[184] These cataclysmic occurrences frequently displace communities, inflict harm upon homes and critical infrastructure, and compromise the integrity of water supplies. In this section, we delve into the profound impacts of recent storm events in Chikwawa District. Specifically, Cyclone Ana, Cyclone Gombe, and Cyclone Freddy have left an indelible mark on the district, inflicting extensive damage and exacerbating an already precarious humanitarian situation.

a. Impact of Recent Storm Events

Cyclone Ana made landfall in Chikwawa District in late January 2022, affecting thousands of residents. The cyclone unleashed extreme flooding, causing widespread destruction of crops and communities. Additionally, it led to substantial power outages and dealt a devastating blow by destroying the Chapananga Bridge, a vital transport artery in northwestern Chikwawa District. The bridge, constructed at a significant cost of MwK 8 billion, stood as a beacon of hope for improved connectivity from the far south to the north and Mozambique.185 Leaving communities stranded and destroying what had promised to be a new and vital transport artery from the far south to the north and to Mozambique. In addition, Cyclone Gombe (11-14 February, 2022) also affected the district, further exacerbating an already dire humanitarian situation.[186] Just one year after Cyclone Gombe, while Chikwawa District was still grappling with recovery and rehabilitation efforts from previous storms, Cyclone Freddy struck in March 2023.[187] This cyclone wreaked havoc, breaking roads, damaging critical infrastructure, including power lines, and leading to the closure of the Kapichira hydro-electric plant. Moreover, Cyclone Freddy washed away nearly ripe crops and caused inundation of vast areas in the Lower Shire Valley. The aftermath witnessed a sharp escalation in food prices, particularly maize, in the district's markets, disproportionately affecting women and girls.[188]

Commenté [LP75]: Could you please add when cyclone Gombe happened?

Commenté [lf76R75]: Done

Commenté [lf77R75]:

Commenté [LP78]: Could you please add a reference to cyclone Freddy impact storyline report?

Commenté [lf79R78]: Done

The destructive winds accompanying storms cause significant damage to infrastructure, including schools, health facilities, roads, bridges, and electricity networks. The damage hampered access to

184 Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. Nature, 529(7584), 84-87. https://doi.org/10.1038/nature16467
185 https://www.mwapata.mw/_files/ugd/dd6c2f_8d0845f037694ebeb3de4d9b040d5d9a.pdf?index=true
[186] https://adore.ifrc.org/Download.aspx?FileId=512689
[187] https://www.msf.org/natural-disasters
188 https://farmersreviewafrica.com/grain-prices-skyrocket-in-malawi-after-cyclone-freddy/

essential services, disrupted transportation, and hindered the delivery of aid and relief efforts. Moreover, strong damaging winds have been recurrent in Malawi, exemplified by events in April 2018 and September 2018. In April 2018, strong winds, accompanied by heavy rains, impacted 1,266 households in Chikwawa district, causing the destruction of roofs and homes. Less than six months later, in September 2018, strong winds damaged another 1,350 households 189 . These instances serve as stark reminders of the immediate and tangible threats posed by storms in the region.

Several factors contribute to the impacts of storms in Chikwawa. Climate change, notably the La Niña phase of the ENSO phenomenon, intensifies rainfall events and influences the frequency and intensity of storms.[190] Deforestation, stemming from unsustainable agricultural practices, charcoal production, and population growth, diminishes the natural water retention capacity of the landscape, increasing the risk of flooding during storms. Building and farming in riverine zones, such as the banks of the Shire and Mwanza Rivers, further amplify this risk. Poor infrastructure planning, including the absence of proper drainage systems and flood control measures, exacerbates the impacts of heavy rainfall and flooding. Additionally, limited early warning systems hinder community preparedness and response efforts, heightening vulnerability and the severity of impacts.[191]

To mitigate the impacts of storms in Chikwawa, various measures can be implemented. Climate change adaptation strategies, such as promoting climate-smart agricultural practices and constructing flood-resistant infrastructure, can enhance community resilience. Reforestation and sustainable land management practices can help restore the natural water retention capacity of the landscape and prevent soil erosion, reducing the risk of flooding. Improved infrastructure planning, including the construction of proper drainage systems and resilient infrastructure, can bolster Chikwawa's resilience to storms. Strengthening early warning systems through the installation of weather monitoring stations and timely dissemination of accurate weather information can enhance preparedness and response efforts. All of these strategies will be explored in detail in the Adaptation Options report for Chikwawa. It is important to note that storms, once a lesser concern in a district historically more impacted by drought and heat, have now become a significant challenge for a region situated in a rain shadow.

b. Risk Profile for Chikwawa

3. The risk profile for Chikwawa highlights the region's susceptibility to tropical storms and cyclones originating from the Mozambique Channel. Climate change projections of 2023, indicate that there will be an increase in cyclone intensity, posing a higher risk of severe wind damage and flooding from future storms. This emphasizes the need for preparedness and adaptation measures to mitigate the potential impacts of these extreme weather events. In terms of rainfall, the annual rainfall projections in the shire valley ADD suggest a slight 1.3 percentage increase in annual precipitation of SSP2.45 and SSP5 scenarios by the year 2080.[192]

Commenté [LP80]: Could you please add a reference. And perhaps the EWS population percentage coverage?

Commenté [lf81R80]:

Commenté [LP82]: Could you please add the reference (which projections), and the % of certainty) for each scenarios? (in a footnote)

Commenté [MOU83R82]: done

[189] https://mixedmigration.org/wp-content/uploads/2023/01/259_Case_Study_7_Malawai.pdf

[190] https://reliefweb.int/report/malawi/climate-and-mobility-case-study-january-2023-chikwawa-malawi-nchalo

[191] Trogrlić, R. S., van den Homberg, M., & Cross, N. R. (2018). Indigenous knowledge and early warning systems in the lower Shire Valley in Malawi.

[192] Government of Malawi, (2023). Climate Projections for the Eight Agricultural Development Divisions in Malawi. Department of Climate Change and Meteorological Services

However, the magnitude of this increase is not significant in these two scenarios. The SSP2.45 scenario predicts a smaller increase of 8mm, while the SSP5.85 scenario indicates a larger increase of 22 mm. These projections indicate that Chikwawa may experience a modest rise in overall rainfall in the future.

4. Furthermore, the projections also indicate that rainfall patterns are expected to become more variable, with an increase in heavy rainfall events. This suggests that the region may experience more intense and concentrated periods of rainfall, which can lead to localized flooding and other associated risks. In particular, the probability of exceeding 150mm of rainfall within a 24-hour period, which serves as a proxy for stormy conditions, is projected to be 0.6 and 6 days SSP5.85 and for SSP2.45, the range from 0.3 to 3 days.[193] However, it is important to note that there is a high level of uncertainty among the climate models regarding the projected changes in mean annual rainfall. The range of projected change by the 2080s, compared to the baseline period of 1991-2020, varies from a decrease of 12% to an increase of 17% under the SSP5.85 scenario. This uncertainty highlights the need for further research and improved modelling techniques to better understand and predict future rainfall patterns in Chikwawa.

Commenté [LP84]: Could you please indicate increase by how much?

Commenté [MOU85R84]: done

a. Floods

a. Types of Floods Affecting Chikwawa

Chikwawa District's geographical positioning within the Shire Valley floodplain renders it susceptible to recurring flooding events[194]. Primarily, fluvial or riverine floods pose the most prevalent threat in this region. These floods occur when heavy rainfall causes the Shire River and its tributaries to breach their banks, inundating the surrounding areas.[195] The Shire River's low-gradient S-shaped meanders contribute to slower water flow, exacerbating overbank flooding across the floodplain.[196] Fluvial floods can persist for weeks and cover extensive areas during the rainy season, as exemplified by the 2019 flooding along the Shire and Ruo rivers, which affected over 50,000 people in Chikwawa District (UN OCHA, 2019).

[193] Government of Malawi, (2023). Climate Projections for the Eight Agricultural Development Divisions in Malawi. Department of Climate Change and Meteorological Services

[194] Ghosh, A., Adhikari, S., Mushtaq, F., Jalal, R., Gauny, J., Tataris, M., Barelli, D., Merzouk, Q., Moloinyane, S., Margaret Mugo, Naeem, M., AmayaOrtiz, L. & Henry, M. 2022. *A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in Malawi.* Rome, FAO. https://doi.org/10.4060/cc2941en
194 Šakić Trogrlić, Robert, Grant B. Wright, Melanie J. Duncan, Marc J. C. van den Homberg, Adebayo J. Adeloye, Faidess D. Mwale, and Joyce Mwafulirwa. 2019. "Characterising Local Knowledge across the Flood Risk Management Cycle: A Case Study of Southern Malawi, Sustainability, 11, 6: 1681. https://doi.org/10.3390/su11061681

[195] Šakić Trogrlić, Robert, Grant B. Wright, Melanie J. Duncan, Marc J. C. van den Homberg, Adebayo J. Adeloye, Faidess D. Mwale, and Joyce Mwafulirwa. 2019. "Characterising Local Knowledge across the Flood Risk Management Cycle: A Case Study of Southern Malawi, Sustainability, 11, 6: 1681. https://doi.org/10.3390/su11061681

[196] Ghosh, A., Adhikari, S., Mushtaq, F., Jalal, R., Gauny, J., Tataris, M., Barelli, D., Merzouk, Q., Moloinyane, S., Margaret Mugo, Naeem, M., AmayaOrtiz, L. & Henry, M. 2022. *A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in Malawi.* Rome, FAO. https://doi.org/10.4060/cc2941en

Intense rainfall also results in pluvial flooding independent of rivers. This occurs when surface runoff accumulates and flows overland from upland areas into the lower plains around Chikwawa District. (Masapula, 2014). Pluvial floods are typically localized and short-lived in comparison to fluvial floods but they still damage infrastructure and crops. For instance, pluvial flooding struck Chikwawa district in January 2023, Tropical Cyclone Freddy in Chikwawa affected approximately 1,112 households (approximately 5,004 people), resulting in one death and three injuries.[197]

Additionally, the presence of steep river tributaries descending from the escarpment highlands makes Chikwawa susceptible to devastating flash floods.[198] These sudden torrents of water rush down river channels at extreme velocities after intense rainfall. The FAO has identified over 15,100 hectares of irrigated cropland at risk of flash flooding in Chikwawa District. 199 Flash floods rapidly destroy irrigation systems, erode fertile topsoil and destroys crops over large areas. Overall, the abrupt onset of the flash floods gives little warning for communities to evacuate. For example, flash flooding in Chikwawa district in 2019 displaced 16,000 households in a matter of hours[200.]

b. Flooding Impacts in Chikwawa

Intense storms and tropical cyclones often bring heavy rainfall that overwhelms resulting in widespread inundation across the district's low-lying plains.[201] For instance, Tropical Storm Ana in January 2022 unleashed over 300mm of rainfall in just two days, leading to extensive flooding that displaced 50,000 people in Chikwawa. Similarly, Tropical Cyclone Gombe in March 2022 exacerbated the flooding, affecting thousands of households.[202]

According to an analysis by the FAO, over 37,500 hectares of land in Chikwawa District were inundated from January to March 2022.203 The area's most prone to flooding lie along the Shire River and its tributaries, particularly in the district's southern regions with lower elevations. The extent of flooding has escalated in recent decades, attributed to environmental degradation and shifts in land use. Deforestation in upland areas has increased runoff, while wetland drainage for agriculture has reduced flood retention capacity. Moreover, floods in Chikwawa have significant implications for food security.

[197] https://floodlist.com/africa/cyclone-freddy-madagascar-mozambique-malawi-march-2023#:~:text=In%20Chikwawa%2C%201%2C112%20households%20(approximately%205%2C004%20people)%20have%20been%20displaced%20with%20one%20death%20and%20three%20injuries%20recorded.%20Around%201%2C300%20households%20(approximately%205%2C850%20people)%20have%20been%20displaced%20in%20Nsanje%2C%20with%20one%20death%20recorded.

198 Ghosh, A., Adhikari, S., Mushtaq, F., Jalal, R., Gauny, J., Tataris, M., Barelli, D., Merzouk, Q., Moloinyane, S., Margaret Mugo, Naeem, M., AmayaOrtiz, L. & Henry, M. 2022. *A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in Malawi.* Rome, FAO. https://doi.org/10.4060/cc2941en

199 Jo Ghosh, A., Adhikari, S., Mushtaq, F., Jalal, R., Gauny, J., Tataris, M., Barelli, D., Merzouk, Q., Moloinyane, S., Mugo, M. , Naeem, M., AmayaOrtiz, L. & Henry, M. 2022. A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in Malawi. FAO, Rome.

200 https://reliefweb.int/report/malawi/2019-flood-response-plan-and-appeal#:~:text=Chikwawa%20(16%2C000%20households)

201 United Nations (UN). (2022). Malawi: Tropical Storm Ana Response – Flash Update No. 3 – 16th February 2022. https://malawi.un.org/en/114823-malawi-floods-flash-update-3-16-feb-2022

202 ECHO. (2022). Mozambique, Malawi – Tropical Cyclone Gombe, update GDACS, INGC, DoDMA, INAM, MET Malawi ECHO Daily Flash of 15 March 2022. https://erccportal.jrc.ec.europa.eu/ECHO-Flash/ECHO-Flash-List/xx/Malawi-Tropical-Cyclone-Gombe-GDACS-RED-Alert-for-rain

203 Jo Ghosh, A., Adhikari, S., Mushtaq, F., Jalal, R., Gauny, J., Tataris, M., Barelli, D., Merzouk, Q., Moloinyane, S., Mugo, M. , Naeem, M., AmayaOrtiz, L. & Henry, M. 2022. A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in Malawi. FAO, Rome.

A comparative study assessing the impacts of flooding on food security in both Chikwawa and Blantyre City, Malawi, revealed that floods have a notably adverse effect on food security for both urban and rural households.[204] The study highlights the need for effective flood management strategies to safeguard the well-being and livelihoods of Chikwawa's residents, particularly in relation to food security and health.

c. Future Risk Projections

Climate projections from the Department of Climate Change and Meteorological Services (DCCMS) in Malawi offer insights into the evolving flood risk in Chikwawa District. The DCCMS predicts complex changes in the probability of extreme daily rainfall exceeding 100mm, a proxy for flash flood conditions. This probability is expected to decrease slightly by 2040 and continue declining through 2080 under both lower (SSP2.45) and higher (SSP5.85) emissions scenarios. However, the overall trajectory of rainfall changes remains deeply uncertain. The Think Hazard app developed by GFDRR states that potentially damaging and life-threatening river floods are expected to occur in Chikwawa District at least once in the next 10 years.205 A study conducted by Bhave et al. (2020) reveals a wide range of potential flooding scenarios in the Lower Shire River basin, with certain models projecting significant flooding events occurring up to 20% of the time.206 This indicates that while extreme daily rains may decline, total rainfall and flood intensity could still increase under climate change.

b. Extreme Heat Events

Extreme heat events are a prominent hazard in the Chikwawa region, particularly prevalent from September to December, preceding the onset of the rainy season. During this period, temperatures in the Shire Valley can soar as high as 46°C, posing severe implications for various aspects of life in the district. These extreme heat events are associated with a range of challenges, affecting public health, agricultural productivity, water resources, and livestock survival. [207]

In particular, during the months of September to December when temperatures escalate to as high as 46°C in the Lower Shire Valley, Chikwawa grapples with multifaceted issues. These encompass significant health concerns such as dehydration and heatstroke, which can have severe consequences, particularly for the most vulnerable members of the population, including the sick, elderly, and very young. The intensified demand for potentially unclean water exacerbates the predicament. Furthermore, the elevated temperatures detrimentally impact agriculture, resulting in crop damage and reduced agricultural productivity. Livestock faces dire circumstances, with heightened mortality rates during heatwaves. Additionally, extreme heat exacerbates water body (lakes, rivers, and streams)

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204 Joshua, M., Stathers, T., Chirwa, R., Ngongondo, C., Lamboll, R., Monjerezi, M., … & Liwenga, E. (2021). A comparative study of the impacts of flooding on food security of urban and rural households in Blantyre city and Chikwawa, Malawi., 35-58. https://doi.org/10.1007/978-3-030-74303-1_3
205 Think Hazard - Chikwawa - River flood
206Bhave, A.G., Bulcock, L., Dessai, S., Conway, D., Jewitt, G., Dougill, A.J. and Mkwambisi, D., 2020. Lake Malawi's threshold behaviour: A stakeholder-informed model to simulate sensitivity to climate change. Journal of Hydrology, 584, p.124671.
207 DCCMS, 2022. Climate Change Projections for Malawi. Department of Climate Change and Meteorological Services, Malawi.

depletion through increased evaporation, compounding water scarcity issues and contributing to fish die-offs that impact the fishing industry.

A disconcerting statistic underscores the association between extreme heat events and human fatalities. Data from the District Health Office reveals that in 2019, Chikwawa experienced a heatwave that tragically claimed four lives. 208 This highlights the immediate and life-threatening nature of extreme heat events in the region, emphasizing the urgent need for attention and action to safeguard the population from the detrimental impacts.

a. Risk Profile

The risk profile for the district indicates that heatwaves are projected to become more frequent and severe in the future due to increasing maximum temperatures.209 Presently, approximately 15% of the district's area experiences perilous heatwave conditions. However, projections suggest a significant expansion of this affected area by the 2080s, reaching 39% or 54% under different scenarios. Alongside increased frequency, the duration of heatwaves is expected to extend.210 By the 2080s, prolonged heatwaves lasting over 5 days are projected to become 2-3 times more likely compared to the present.211 This implies that the district will endure more prolonged periods of extreme heat, which can severely impact human health, agriculture, and other sectors. The prevalence of heatwaves, defined as areas with mean maximum temperatures exceeding 30.5°C, is projected to expand from the current 15% to 39% or 54% by the 2080s. [212] This indicates a substantial increase in the geographic extent of heatwave conditions.

c. Droughts and Dry Spells

Droughts and dry spells are recurring and formidable disasters in Chikwawa district, with far-reaching consequences for the local community.[213] Droughts and dry spells have had major impacts on agriculture, food security, nutrition, water availability, and livelihoods in Chikwawa district, southern Malawi. Chikwawa has experienced an increase in the frequency of droughts and dry spells over the past several decades due to climate change, with significant impacts on crop yields and food availability.[214] During the 2015-2016 El Niño event, Chikwawa experienced prolonged dry spells which led to a poor harvest and 45% acute food insecurity.[215] The country is experiencing extreme food

208 https://www.maraviexpress.com/chikwawa-district-council-investigating-if-four-deaths-registered-is-due-to-heat-wave/
209 https://www.climatecentre.org/wp-content/uploads/RCRC_IFRC-Country-assessments-Malawi_Final3.pdf
210 Department of Climate Change and Meteorological Services (DCCMS), 2021. Climate Projections for the Eight Agricultural Development Divisions in Malawi. Ministry of Environment, Climate Change and Meteorological Services, Lilongwe, Malawi.
211 Ibid.
212 DCCMS, 2022. Climate Change Projections for Malawi. Department of Climate Change and Meteorological Services, Malawi.
213 Stanton, M., Mkwanda, S., Debrah, A., Batsa, L., Biritwum, N., Hoerauf, A., … & Kelly-Hope, L. (2015). Developing a community-led sms reporting tool for the rapid assessment of lymphatic filariasis morbidity burden: case studies from malawi and ghana. BMC Infectious Diseases, 15(1). https://doi.org/10.1186/s12879-015-0946-4
214 https://openknowledge.worldbank.org/server/api/core/bitstreams/dda8ad4c-f1ab-5704-bf0e-a515e37cbafc/content
215 https://reliefweb.int/report/malawi/malawi-vulnerability-assessment-committee-results-2016

insecurity, approximately 33% below the five-year average. This is as a result of persistent dry spells, unpredictable rainfall and flooding.216

Dry spells during critical crop growth stages, especially around the flowering period in January-February, can have devastating impacts on yields. A case study by Makwara et al. (2018) found that a 14-day dry spell during the 2015-2016 growing season in Chikwawa resulted in complete crop failure for many farmers. Average maize yields were 61% lower compared to normal rainfall years. With poor harvests, household food reserves become depleted leading to increased food insecurity. After the 2015-2016 drought, the number of food insecure people in Chikwawa rose from 14% pre-harvest to 45% post-harvest.[217] Livelihoods focused on rain-fed agriculture are also negatively affected by reduced crop production during droughts and dry spells in Chikwawa. Income from crop sales is an important livelihood source for rural households. With low yields and production, income also declines.

Water scarcity is another major impact. Chikwawa depends primarily on shallow wells, boreholes, rivers and streams for water. During droughts and dry spells, many of these sources dry up or have reduced supply. Women and children especially spend more time travelling longer distances to collect water from remaining functional sources.[218] Poor water access also leads to negative health and hygiene outcomes. Overall, frequent droughts and dry spells place considerable strain on food security, nutrition, livelihoods, and water availability in Chikwawa district. Climate change is expected to increase the frequency and severity of these events, making adaptation and preparedness efforts essential.

d. Conclusion

The hazards identified in the Chikwawa District Climate Risk Assessment Report, including storms, floods, extreme heat events, and droughts, pose significant risks to the community and its socio-economic well-being. The consequences of these hazards range from infrastructure damage and crop losses to loss of life and increased poverty levels. In a recent workshop carried out for this work, the single greatest impact that local people fear and experience as a result, especially of flood and drought is hunger, yet, in a recent survey conducted in Nchalo, a town in the district, 72% of respondents said that they had not considered moving and of those that were, a majority said that they had insufficient resources to move or nowhere to move to.[219] To mitigate these risks, proactive strategies for disaster preparedness, flood management, heat-related challenges, and sustainable land use and water resource management are essential. By implementing these strategies, Chikwawa can enhance its resilience to climate change and protect the livelihoods of its residents.

216 https://planetgeogblog.wordpress.com/2016/06/07/the-impact-of-el-nino-on-the-lower-shire-valley-malawi-a-preliminary-observation-by-jane-maher/#:~:text=The%20country%20is%20experiencing%20extreme%20food%20insecurity%2C%20approximately%2033%25%20below%20the%20five%20year%20average.%20This%20is%20as%20a%20result%20of%20persistent%20dry%20spells%2C%20unpredictable%20rainfall%20and%20flooding.

217 https://reliefweb.int/report/malawi/malawi-vulnerability-assessment-committee-results-2016

218 Emmanuel Charles Nkomwa, Miriam Kalanda Joshua, Cosmo Ngongondo, Maurice Monjerezi, Felistus Chipungu,.2014. Assessing indigenous knowledge systems and climate change adaptation strategies in agriculture: A case study of Chagaka Village, Chikhwawa, Southern Malawi, Physics and Chemistry of the Earth, Parts A/B/C, Volumes 67–69, Pages 164-172. ISSN 1474-7065. https://doi.org/10.1016/j.pce.2013.10.002.

219 https://mixedmigration.org/wp-content/uploads/2023/01/259_Case_Study_7_Malawai.pdf

5. Sectoral impacts of climate hazards in Chikwakwa district

a. Agriculture

In Chikwakwa district, agriculture and crop production have been severely impacted by climate hazards, leading to widespread repercussions. These hazards, particularly floods, have wreaked havoc on key crops, livestock, and irrigation systems within the agricultural sector of Chikwawa. Floods have left no Extension Planning Area (EPA) in Chikwawa District untouched, with reports indicating that a staggering 42,276.7 hectares of various crops were inundated.[220] The year 2015 witnessed an exceptional and historically unprecedented level of rainfall, surpassing all previous records in Malawi. This deluge, along with a subsequent 400% increase in rainfall in the Southern Region compared to the long-term mean, resulted in devastating floods.[221,222,223]. One of the most significant consequences of these climatic extremes has been the substantial decline in maize yields, with losses reaching up to 60% during periods of extreme drought and flooding.[224] Such fluctuations adversely affect both food availability and income for smallholder farmers.

Additionally, the production of sugarcane, a vital contributor to Malawi's export earnings and a significant source of employment, saw a decline in output by approximately 30-40% during drought years. This drop in production has led to reduced supply to processing mills. Prolonged dry spells during critical growth stages for sugarcane production resulted in crop failures and food shortages.[225] The severity of these impacts can be attributed partly to the lack of irrigation infrastructure, limited adoption of resilient farming practices, and cultivation on marginal lands susceptible to flooding. The cost of damages to irrigation infrastructure alone reached a staggering 623 million Malawian Kwacha in Chikwawa District, the highest in the country. To compound these challenges, Malawi faced a severe drought in 2015/2016, with significantly below-average rainfall received during critical periods for agriculture.[226]

Chikwawa continued to grapple with the aftermath of the 2015 floods while enduring a devastating drought, which persisted into the following season, exacerbating food insecurity and livelihood loss.[227] Chikwawa was reported to have lost 90% of their crops caused by the drought, while still recovering from the losses caused by the 2015 floods. The drought continued across the following season, 2016/2017 which further exacerbated food insecurity and loss of livelihoods.[228229]

220 Chikwawa District Agriculture Office. 2022. Special Report on Floods. Ministry of Agriculture
221 Reliefweb (2020). *Southern Africa: Floods - Jan 2015*. Available online at: https://reliefweb.int/disaster/fl-2015-000006-mwi (accessed January 19, 2020).
222 Government of Malawi (2015b). *Malawi 2015 Floods Post Disaster Needs Assessment Report* (PDNA).
223 Hendriks, T., and Boersma, F. (2019). Bringing the state back in to humanitarian crises response: disaster governance and challenging collaborations in the 2015 Malawi flood response. *Int. J. Disaster Risk Red.* 40, 1–7. doi: 10.1016/j.ijdrr.2019.101262
224 Mwale, F.D. et al. 2015. Quantifying vulnerability of rural communities to flooding in SSA: A contemporary disaster management perspective applied to the Lower Shire Valley, Malawi. Int. J. Disaster Risk Reduct. 12: 172–187.
225 Government of Malawi (2016). *Malawi Drought 2015-2016 Post Disaster Needs Assessment* (PDNA).
226 Government of Malawi (2016). *Malawi Drought 2015-2016 Post Disaster Needs Assessment* (PDNA).
227 Government of Malawi (2016). *Malawi Drought 2015-2016 Post Disaster Needs Assessment* (PDNA).
228 Government of Malawi (2017). *2016/2017 Food Insecurity Response Plan* (FIRP).
229 Mazvimavi, K., Murendo, K., and Chivenge, P. (2017). *The impacts of the El Niño-induced drought on seed security in Southern Africa: implications for humanitarian response and food security*. Technical Report, ICRISAT.

The beginning of 2019 saw several tropical cyclones affecting southern Africa. Malawi was first severely affected by the continuous and extensive rainfalls caused by the Tropical Cyclone Desmond during end January 2019. Severe flooding occurred in southern Malawi, affecting almost 16,000 people Chikwawa (International Federation of Red Cross Red Crescent Societies [IFRC], 2019).230 In early March of the same year, heavy rains intensified into Cyclone Idai, causing further losses in Chikwawa, including 11% of the maize harvest and significant damage to irrigation infrastructure. [231] Additionally, the geographical location of crops in fertile flood plains and the inadequate flood protection measures in place made them highly vulnerable to flooding.[232] Furthermore, rising temperatures exacerbated crop diseases, and infestations of Fall Armyworm since 2016 posed a significant threat to food security by attacking staple crops such as sorghum, millet, and maize.233 The floods also took a toll on livestock in both Chikwawa and Nsanje districts, resulting in the loss of 25,444 livestock units valued at MK1.36 billion.[234]

b. Forestry (Including Forest Fires and Productivity)

a. Deforestation

Deforestation in Chikwawa poses a severe threat, primarily driven by charcoal production and agricultural activities.[235] This alarming trend is rapidly depleting the district's forest reserves, with far-reaching consequences. The diminishing tree cover not only disrupts the region's natural carbon sink but also heightens the risk of flooding and soil erosion.[236] These consequences have detrimental effects on the local ecosystem and communities. As trees dwindle, their capacity to absorb rainfall diminishes, resulting in more pronounced flood runoff and increased susceptibility to flooding and soil loss. These consequences not only harm the local ecosystem but also impact communities. Addressing deforestation is of paramount importance to mitigate these risks and restore the ecological balance in Chikwawa. The absence of trees and vegetation exacerbates the impact of floods significantly.[237]

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230 International Federation of Red Cross Red Crescent Societies [IFRC] (2019). *Emergency Plan of Action (EPoA), Malawi Floods*. Available online at: https://reliefweb.int/sites/reliefweb.int/files/resources/MDRMW014do.pdf (accessed December 6, 2020).

231 Government of Malawi (2019). *Malawi 2019 Floods Post Disaster Needs Assessment* (PDNA).

232 Rahman, M., Di, L., Yu, G., Lin, L., & Yu, Z. (2020). Remote sensing based rapid assessment of flood crop damage using novel disaster vegetation damage index (dvdi). International Journal of Disaster Risk Science, 12(1), 90-110. https://doi.org/10.1007/s13753-020-00305-7

233 https://reliefweb.int/report/malawi/climate-and-mobility-case-study-january-2023-chikwawa-malawi-nchalo#:~:text=Crop%20disease%20is%20exacerbated%20by%20rising%20temperatures%2C%20and%20infestations%20of%20Fall%20Armyworm%20(Spodoptera%20frugiperda)%20have%20occurred%20since%202016.8%20This%20pest%20poses%20a%20significant%20threat%20to%20food%20security%20as%20it%20feeds%20on%20more%20than%2080%20plant%20species%2C%20including%20Malawi%E2%80%99s%20staple%20crops%20of%20sorghum%2C%20millet%2C%20and%20maize.9

235 https://reliefweb.int/report/malawi/climate-and-mobility-case-study-january-2023-chikwawa-malawi-nchalo#:~:text=deforestation%20both%20for%20agricultural%20land%20and%20for%20fuel.

236 https://news.trust.org/item/20190724135908-nijs4/

237 https://www.voanews.com/a/cyclone-gombe-kills-7-damages-houses-and-roads-in-malawi/6484818.html#:~:text=%E2%80%9CBecause%20most%20of%20the%20land%20is%20bare%2C%20no%20trees%2C%20no%20vegetation%2C%20so%2C%20when%20these%20waters%20come%2C%20the%20impact%20of%20these%20floods%20is%20very%2C%20very%20high.%20And

b. Invasive Species

Another pressing issue in Chikwawa is the rapid proliferation of invasive species, exemplified by *Prosopis juliflora*.[238] This thorny invader, thriving in tired and infertile soil unsuitable for other species, outcompetes native vegetation and disrupts the ecological equilibrium. Its proliferation is partly attributable to climate variability. The invasion of such species not only jeopardizes the district's biodiversity but also disrupts critical ecosystem services, including soil fertility and water regulation.[239] Preserving and managing Chikwawa's natural habitats, including addressing invasive species, requires the allocation of resources, education, and training.[240]

c. Wildfire Vulnerability

Chikwawa faces a significant concern regarding the vulnerability of timber plantations to wildfires during prolonged dry spells and extreme heat, which desiccate the forestry. In areas like TA Makhwira, the peak fire season typically commences in late October and lasted around seven weeks.[241] Between 2001 and 2022, Chikwawa lost 20 hectares of tree cover to fires and 4.74 thousand hectares to various other drivers of loss.[242]

c. Fisheries (capture and aquaculture)

a. Impact of Floods on Fish Habitats

One of the notable concerns within the fisheries sector is the impact of floods. Flooding events lead to increased turbidity and siltation in water bodies, which harm fish habitats. These changes in water quality and sedimentation disrupt the delicate balance of aquatic ecosystems, affecting fish populations and the overall health of the fisheries sector.

Consequences for Fish Farming:

The flood affected several fishponds and aquaculture facilities in Chikwawa and Nsanje districts. A total of 17 fish in Nsanje and 92 fish ponds in Chikwawa district were affected.243 Most ponds suffered damage on the inlet and outlet, and most fish were swept away by the flood. The 2022 Chikwawa floods resulted in the damage of 92 fish ponds, leading to a severe loss of fish stocks. [244] When fish ponds are inundated by floodwaters, pollutants and invasive species enter the ponds disturbing the micro-ecosystem balance carefully nurtured by fish farmers, dependent on income from these capital-intensive investments. This not only impacts the incomes of fisherfolk but also reduces the protein

[238] https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID_ATLAS_Malawi_FFP_CRP.pdf
[239] https://mwnation.com/govt-launches-fight-against-invasive-species/
[240] https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID_ATLAS_Malawi_FFP_CRP.pdf
[241] https://www.globalforestwatch.org/dashboards/country/MWI/3/9/?map=eyJjYW5Cb3VuZCI6dHJ1ZX0%3D#:~:text=In%20TA%20Makhwira%20the%20peak%20fire%20season%20typically%20begins%20in%20late%20October%20and%20lasts%20around%207%20weeks.
[242] https://www.globalforestwatch.org/dashboards/country/MWI/3/?category=fires#:~:text=From%202001%20to%202022%2C%20Chikwawa%20lost%2020%20ha%20of%20tree%20cover%20from%20fires%20and%204.74%20kha%20from%20all%20other%20drivers%20of%20loss.
[243] https://www.mwapata.mw/_files/ugd/dd6c2f_8d0845f037694ebeb3de4d9b040d5d9a.pdf?index=true

[244] https://www.mwapata.mw/_files/ugd/dd6c2f_8d0845f037694ebeb3de4d9b040d5d9a.pdf?index=true

intake for households dependent on fishing. Recurrent flooding and heavy silt loads have also led to a reduction in fish habitats and breeding grounds, causing the disappearance of important fish species like Oreochromis shiranus (the Shire Tilapia and, coincidentally, the species farmed by 90% of Malawi's fish farmers),[245] from Chikwawa's rivers. Addressing these challenges is crucial for the sustainability of fish farming and the well-being of both farming and capture fishing communities.

d. Infrastructure

a. Vulnerability of Infrastructure

One pressing concern resulting from climate extreme events is the vulnerability associated with weak and inadequate infrastructure. Storms and floods often render roads impassable, isolating communities and hindering the delivery of goods and services. For instance, the principal north-south trunk road of the country and a vital link between Nsanje and Chikwawa districts as an impact of heavy flooding.246 Rural access roads are particularly susceptible to prolonged closures after floods, leading to delays in aid distribution and significant income losses for small businesses that rely on these routes for trade. The report emphasizes the need for more resilient infrastructure capable of withstanding the challenges posed by climate-induced disasters.

b. Disruption of Transportation Networks

Bridges, essential for river crossings, consistently fail to withstand the force of floods, further disrupting transport and communication networks.[247] The report underscores the critical need for resilient infrastructure to ensure the uninterrupted flow of people and goods. By strengthening bridges and improving their design to withstand flood events, Chikwawa can enhance the resilience of its transportation networks and maintain connectivity even during extreme weather events.

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c. Impact on Essential Services

Climate-related hazards not only inflict physical damage on infrastructure but also disrupt the provision of vital public services. On January 26, 2022, Chikwawa fell victim to the destructive floods

[245] https://www.cabi.org/gara/mobile/FullTextPDF/2013/20133184530.pdf
[246] https://www.voanews.com/a/cyclone-gombe-kills-7-damages-houses-and-roads-in-malawi/6484818.html#:~:text=The%20report%20further%20indicates%20that%20the%20Chikwawa%2DNsanje%20Road%20has%20been%20cut%20off%20in%20the%20Chikwawa%20District%2C%20making%20the%20Nsanje%20District%20inaccessible%20by%20road.
[247] https://www.google.com/search?q=Bridges%2C+essential+for+river+crossings%2C+consistently+fail+to+withstand+the+force+of+floods+in+chikwawa%2C+further+disrupting+transport+and+communication+networks.+&sca_esv=596495099&rlz=1C5CHFA_enMW1044MW1055&sxsrf=ACQVn0_Lfl6jZTWbBiBz4EFC3bEgdNcCoA%3A1704707762355&ei=ssabZbOlFeKehbIPv8O0mAw&ved=0ahUKEwizxvukw82DAxViT0EAHb8hDcMQ4dUDCA8&uact=5&oq=Bridges%2C+essential+for+river+crossings%2C+consistently+fail+to+withstand+the+force+of+floods+in+chikwawa%2C+further+disrupting+transport+and+communication+networks.+&gs_lp=Egxnd3Mtd2l6LXNlcnAioQFCcmlkZ2VzLCBlc3NlbnRpYWwgZm9yIHJpdmVyIGNyb3NzaW5ncywgY29uc2lzdGVudGx5IGZhaWwgdG8gd2l0aHN0YW5kIHRoZSBmb3JjZSBvZiBmbG9vZHMgaW4gY2hpa3dhd2EsIGZ1cnRoZXIgZGlzcnVwdGluZyB0cmFuc3BvcnQgYW5kIGNvbW11bmljYXRpb24gbmV0d29ya3MuIDIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJzIHECMY6gIYJ0jdU1CpB1i9UXABeACQAQCYAQCgAQCqAQC4AQPIAQD4AQH4AQKoAgriAwQYACBBiAYB&sclient=gws-wiz-serp#:~:text=Malawi%202023%20Tropical,net%20%E2%80%BA%20download

caused by tropical storm Ana, which led to the catastrophic destruction of the Kapichira dam.[248] This calamity had particularly severe consequences for the electricity sector, notably impacting the 129.6 MW capacity Kapichira Hydropower Plant. The damage inflicted by the floods left the plant incapacitated due to the accumulation of debris and sediment. [249] The implications of this damage were dire, as it raised the spectre of nationwide blackouts that could persist for weeks. In March 2023 as a precaution against the same thing happening at Kapichira due to the heavy floods generated by Cyclone Freddy, the turbines were switched off to avoid damage from debris causing serious power cuts throughout the country while the power houses were cleaned out after the flood subsided. Such scenarios not only impact Chikwawa but also threaten health, education, government and business activities as well as those domestic homes that have grid access throughout Malawi.[250] During times of blackout, many households turn to charcoal for cooking which is one reason why most homes in Malawi, even amongst the well-off, keep a stock of charcoal in case it is needed.

In addition, people who were displaced from the storm used school, churches, hospitals, shelters, and made-up campsites as their evacuation centres. [251] Regrettably, these living conditions posed substantial challenges for school-going children, rendering it exceedingly difficult for them to attend classes. As a result, the storm's impact reverberated across the educational landscape, affecting a staggering 398,908 learners across 476 schools. Accordingly, nearly 50% of the learners in the district were compelled to abandon their schooling.[252] Compounding this educational setback, the learners suffered losses of their school materials, including textbooks and notebooks. The situation was further exacerbated by the complete destruction of some schools due to the floods, dealing a severe blow to the district's literacy rate. [253]

e. Water Resources

a. Impacts of Floods on Water Quality

Floods contribute significantly to soil erosion and siltation, degrading the quality of water sources in Chikwawa. [254] The increased runoff carries pollutants from various sources, including land and buildings, resulting in contaminated water bodies. A striking example is the 2019 flooding induced by Cyclone Idai, which severely disrupted households' access to water in Magalasi Village, Chikwawa District, Malawi[255]. The sediment load brought by these floods compromises the purity of surface water bodies, upon which communities rely for drinking, fishing, and recreation. This contamination

[248] https://documents1.worldbank.org/curated/en/910591655323455566/pdf/Malawi-Emergency-Power-Restoration-Project.pdf
[249] Ibid
[250] https://crisis24.garda.com/alerts/2022/02/malawi-power-supply-disruptions-possible-nationwide-through-at-least-mid-2022
[251] https://reliefweb.int/report/malawi/unicef-malawi-humanitarian-situation-report-tropical-storm-ana-15-february-2022
[252] Ibid
[253] Ibid
[254] https://mixedmigration.org/wp-content/uploads/2023/01/259_Case_Study_7_Malawai.pdf
[255] Joshua, Miriam & Chirwa, Ruth & Ngongondo, Cosmo & Monjerezi, Maurice & Mwathunga, Evance & Kasei, Raymond. (2021). Impact of Floods on Access to Drinking Water: A Focus on 2019 Floods in Magalasi Village in Chikwawa District, Malawi. 10.1007/978-3-030-74192-1_11.

posed severe health risks to the local population.[256] Another illustrative example was the situation in 2022 in March, Malawi's health ministry reported a cholera outbreak, with Chikwawa being one of the hardest-hit districts, where 1082 cases and 44 deaths were recorded.[257]

Drought presents a different set of challenges within the water sector. During droughts, critical shortages of water for domestic, agricultural, and industrial purposes become evident. In severe cases, like the 2016 drought, many water points dried up entirely, leaving communities without access to safe and reliable water sources.[258] Shallow household wells, which are a lifeline for many, either dry up completely or become contaminated during prolonged dry spells. This disproportionately affects women and children who bear the burden of walking long distances to distant water points, exacerbating the hardship caused by water scarcity.[259]

f. Gender Dimension

The impact of climate-related hazards on gender, specifically women, girls, children, the elderly, and disabled individuals, in Chikwawa District, Malawi, is significant. Malawian society is highly patriarchal, and gender inequalities persist. [260] Women in Malawi are particularly vulnerable to climate change and variability, as they often live in rural areas and account for a majority of smallholder farmers.[261] The impact of climate-related hazards on women in Chikwawa District is further exacerbated by existing gender roles and inequalities. Women are responsible for household food production and farming, while men often control access to land, credit, and agricultural inputs. [262] According to World Bank data, 82% of Malawi’s population live in rural areas, and women account for 65% of smallholder farmers, making them particularly exposed to food insecurity.[263] Women are often dependent on natural resources, and many earn a living in the informal sector, leaving them less able to withstand economic and environmental shocks.[264] This limits women's decision-making power, control over resources, and access to credit, hindering their ability to adapt to climate change. Additionally, women in Chikwawa District bear a disproportionate burden of unpaid care work and household

[256] https://www.unicef.org/malawi/stories/locals-fight-cholera-hygiene-campaigns#:~:text=On%20occasion%2C%20it%20also%20floods%20the%20surrounding%20area.%20And%20with%20floods%20come%20water%20borne%20diseases%2C%20chief%20among%20them%2C%20cholera.

[257] https://www.unicef.org/malawi/stories/locals-fight-cholera-hygiene-campaigns#:~:text=In%20March%2C%20Malawi%E2%80%99s%20health%20ministry%20reported%20that%20cholera%20had%20broken%20with%20Chikwawa%20being%20one%20of%20the%20worst%20hit%20districts.%20To%20date%2C%201082%20cases%20and%2044%20deaths%20have%20been%20recorded.%20%C2%A0

[258] https://health.bmz.de/toolkits/climate-health/vulnerability-assessments/a-vulnerability-assessment-in-chikwawa-malawi/#:~:text=Other%20commonly%20reported,risk%20of%20disease.

[259] https://www.who.int/news/item/06-07-2023-women-and-girls-bear-brunt-of-water-and-sanitation-crisis---new-unicef-who-report

[260] Coulibaly, Y.J., Mbow, C., Sileshi, G.W., Beedy, T., Kundhlande, G. and Musau, J. (2015) Mapping Vulnerability to Climate Change in Malawi: Spatial and Social Differentiation in the Shire River Basin. *American Journal of Climate Change*, **4**, 282-294. http://dx.doi.org/10.4236/ajcc.2015.43023

[261] https://reliefweb.int/report/malawi/climate-change-putting-women-girls-malawi-greater-risk-sexual-violence

[262] https://www.equalitynow.org/news_and_insights/malawi-cyclone-freddy-has-put-women-girls-in-malawi-at-greater-risk-of-sexual-abuse-exploitation/#:~:text=Women%20make%20up,time%20to%20learn.%E2%80%9D

[263] https://reliefweb.int/report/malawi/climate-change-putting-women-girls-malawi-greater-risk-sexual-violence

[264] Ibid

responsibilities, which intensify during climate-related emergencies.[265] They play a central role in managing the aftermath of climate emergencies, such as providing food and caregiving, but are also more vulnerable to the impacts of extreme weather events. [266]

Girls in Chikwawa District are also disproportionately affected by climate-related hazards. They face higher rates of child and forced marriage, as parents may view marriage as a coping strategy to alleviate monetary difficulties and protect their daughters from sexual violence.[267] It is estimated that around 1.5 million girls in Malawi are at risk of becoming child brides as a direct result of climate change. [268] Furthermore, girls often experience financial hardship, leading to pressure to drop out of school and engage in domestic work or find paid employment. This increases their susceptibility to exploitation, including false promises made by traffickers about jobs and education opportunities. The impact of climate-related hazards on women and girls in Chikwawa District is also evident in their access to resources. Women and girls are responsible for gathering water and firewood, which are increasingly scarce due to environmental degradation. They often have to travel further to acquire these resources, putting them at risk of physical harm and sexual harassment. Women in camps for displaced individuals have reported incidents of sexual harassment, including being asked to perform sexual acts in exchange for aid. [269] However, many women are reluctant to report these incidents due to the lengthy prosecution process, scepticism, stigmatization, and fear of blame or domestic violence from their husbands.

Risk Summary

Chikwawa district is highly vulnerable to climate change impacts and extreme weather events like storms, floods, and droughts. The predominantly rural population relies heavily on climate-sensitive livelihoods like rain-fed agriculture, making them highly exposed. Low levels of infrastructure and public services limit the capacity to cope with disasters. Recurrent flood and drought events over the past decade, as recently as Tropical Storm Ana in 2022, have disrupted agriculture, damaged infrastructure, and strained communities still recovering from previous emergencies. Climate projections predict increased frequency and severity of extreme weather, posing further risks. Key risks for Chikwawa district include fragile livelihoods and food security, low community resilience and recovery capacity after disasters, constrained local government capacity and resources to support adaptation and emergency response, and lack of strategies to protect lives and assets from intensifying climate hazards. Building resilience through livelihood diversification, disaster preparedness, and climate-smart infrastructure is critical.

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[265] https://www.equalitynow.org/news_and_insights/malawi-cyclone-freddy-has-put-women-girls-in-malawi-at-greater-risk-of-sexual-abuse-exploitation/#:~:text=Women%20make%20up,time%20to%20learn.%E2%80%9D

[266] Ibid

[267] https://reliefweb.int/report/malawi/climate-change-putting-women-girls-malawi-greater-risk-sexual-violence

[268] Ibid

[269] https://www.equalitynow.org/news_and_insights/malawi-cyclone-freddy-has-put-women-girls-in-malawi-at-greater-risk-of-sexual-abuse-exploitation/#:~:text=Women%20are%20complaining,are%20well%20founded.

Annex 2: Phalombe District – Climate Risk Assessment Report

1. Introduction

Phalombe district, situated in the Southern Region of Malawi, boasts a Tropical wet and dry or savanna climate and encompasses an area spanning approximately 1,365 km^2. It shares its boundaries with Chiradzulu District to the northwest, Thyolo District to the west, Mulanje District to the south, and Mozambique to the east. The northern boundary is the southern shoreline of Lake Chilwa. Phalombe forms an integral part of the Chilwa Basin, a vital geo-ecological region within Malawi. The extensive network of rivers in the area supports diverse ecosystems and serves both agricultural and domestic purposes. On an average year, the district receives approximately 1129 mm of precipitation and maintains a yearly temperature average of 21.3ºC (DCCMS, 2023). At the same time, the southern (Mulanje Massif) portion of Phalombe shares vast similarities with the Shire Highlands, in terms of climate and terrain. The Shire Highlands are known for a cooler and more temperate climate compared to the lowlands of Malawi, making it an ideal location for agriculture and tourism. The rest of Phalombe District lies in the flattish and highly exposed lacustrine Chilwa basin. Phalombe has been identified as one of the most the most vulnerable districts for the negative impacts of climate change in Malawi (GoM, 2019).270

The socio-economic profile of Phalombe District encompasses various vital sectors, including agriculture, small-scale businesses, tourism, forestry, and fisheries. Agriculture takes a central role, involving both commercial and subsistence farming, with a focus on crops like maize, legumes, tobacco, tea, and coffee. These agricultural activities are often strongly dependent on climate conditions. Additionally, livestock farming and a vibrant small-scale business environment play substantial roles in bolstering the local economy. For this reason, the natural climate system plays quite an important function. In this report, we highlight key climate hazards affecting Phalombe, their drivers as well as the impact they have on the natural environment and socio-economic systems respectively.

2. Climate Drivers and Their Impacts on Phalombe, Malawi.

The climate of Phalombe is an accumulation of various factors including the El-Nino Southern Oscillation System (ENSO) and the location of the Inter-Tropical Convergence Zone (ICTZ). These phenomena have a substantial impact on the country's agriculture and water resources. El Niño events, characterized by warmer sea surface temperatures in the equatorial Pacific Ocean, are often associated with drier conditions and droughts in Malawi. In contrast, La Niña events, marked by cooler sea surface temperatures, can bring increased rainfall and the risk of flooding to Phalombe District.

[270] Government of Malawi (2019). '2019 Floods Post Disaster Needs Assessment Report'. Department of Disaster Management Affairs (DoDMA), Lilongwe.

The Inter-Tropical Convergence Zone (ITCZ) exerts a significant influence on Malawi's overall climate (Tadeyo et al, 2020).[271.] This zone represents a band of trade winds converging near the equator, and its position shifts with the changing seasons. During the wet season, the ITCZ moves southward, bringing much-needed rainfall to Southern Africa (Davis et al, 2017),[272] which is crucial for agriculture and water resources in Malawi. Conversely, when the ITCZ shifts northward, it can result in dry spells, adversely affecting crop growth and the availability of water resources.

Other ocean movements directly affecting the climate of Southern Malawi is the Indian Ocean Dipole Movement (Kumbuyo et al, 2019).[273] The IOD is defined by disparities in sea surface temperatures across the Indian Ocean and is known for its far-reaching impact on regional climate patterns, particularly in the southern region of Malawi. Positive IOD events can lead to above-average rainfall, benefiting agriculture, while negative IOD events are associated with drier conditions that result in droughts and dry spells, posing challenges for food security and water availability.

Tropical cyclones, although not directly hitting Malawi, have had an impact the country as the remnants of these storms, particularly in the Mozambique Channel, can bring heavy rainfall and the risk of flooding. Previously, tropical cyclones were not considered to be a threat as Malawi is not a coastal country. However, there has been growing evidence that tropical storms and cyclones could be a threat to Malawi's climate as evidenced by Tropical Storms Delphina (2002), Chedza (2015), Idai (2019), Kenneth (2019), Ana (2021), Gombe (2022), and Freddy (2023). In the face of climate change, these storms are expected to intensify due to increasing temperatures that affect their formation. Phalombe has been affected by many of these storms, and the effects of such have been more pronounced in recent years.

The increased occurrence of heavy rains has resulted in more frequent and severe flooding events, often driven by rivers like Mombezi, Namazi, and Phalombe. These floods not only submerge farms but also wreak havoc on crops, livestock, infrastructure, and tragically, contribute to fatalities during cyclones.

Furthermore, landslides are becoming more commonplace, particularly on the slopes of the Mulanje Mountain massif, causing significant harm to both human and animal life while burying houses and farmlands. The district is also contending with extreme temperature fluctuations having been observed around Lake Chilwa. Similarly, drought events have been noted, with residents witnessing rains disappearing as crops approach maturity. Additionally, mining activities in the Mulanje Mountains are silting rivers and Lake Chilwa, especially during floods, further compounding environmental challenges. These evolving climate risks necessitate adaptive strategies, preparedness measures, and potential mitigation efforts to protect the local population and their livelihoods. In particular, mitigating the impact of floods, landslides, drought, temperature extremes, and the associated consequences is vital to safeguarding Phalombe District's residents and their well-being.

Commenté [LP88]: Reference please

3. Climate-Related Hazards and Vulnerabilities in Phalombe

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[271] Tadeyo, E., Chen, D., Ayugi, B., & Yao, C. (2020). Characterization of spatio-temporal trends and periodicity of precipitation over Malawi during 1979–2015. *Atmosphere*, *11*(9), 891.

[272] Davis, C. L., & Vincent, K. (2017). Climate risk and vulnerability: A handbook for Southern Africa.

[273] Kumbuyo, C. P., Shimizu, K., Yasuda, H., & Kitamura, Y. (2015). Linkage between Malawi Rainfall and Global Sea Surface Temperature. *Journal of Rainwater Catchment Systems*, 20, 2, 7-13.

a. Floods

Commenté [LP89]: Could you please include references to the FRA report where relevant?

Recurring floods represent a notable climate-related hazard that has a profound impact on the residents of Phalombe. These flood events, primarily triggered by heavy rainfall and consequential river overflow present substantial challenges to the local environment, economic activities, and the overall quality of life of the population. Phalombe has been identified as one of the most vulnerable districts being the most affected by flood disasters.

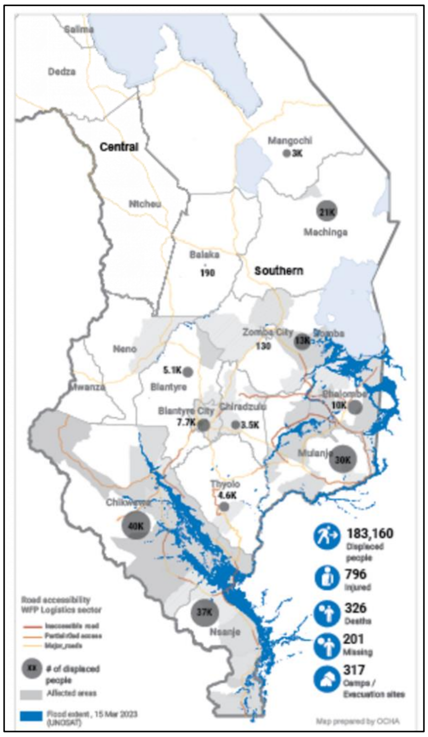
For example, the 2015 floods in Phalombe, Malawi, were a devastating natural disaster brought on by heavy and persistent rainfall during the rainy season. These floods were part of a larger flood event that affected multiple regions of the country. The usual rainfall season coincided with a tropical storm system (ex-cyclone Chedza) that formed in the Mozambique Channel. Cyclone Chedza's impact on Malawi occurred as a result of its trajectory and the heavy rainfall associated with it. While Cyclone Chedza didn't directly make landfall in Malawi as a fully organized tropical cyclone, the remnants of the cyclone, including the moisture and rainfall associated with it, contributed to severe flooding in the country in January 2015.

Cyclone Chedza formed as a tropical depression on January 7, 2015, in the southwestern Indian Ocean, and made second landfall over Mozambique in January 17, 2015; causing heavy rainfall, strong winds, and flooding to the Southern and Central Malawi. The UN reported that the Southern Region of Malawi received 400 percent higher rainfalls than usual, which led to the Shire River reaching its highest levels in 30 years (Steiro, 2016)[274.] A similar event occurred in March 2019 when a similar low pressure system (Cyclone Idai) with a double hitting system formed in the Mozambique Channel and extended its residual impacts on the South and Eastern Malawi (Nicholson et al, 2019).[275.] Tropical Storm Ana and Cyclone Gombe followed up in January and March 2022, causing considerable damage to lives and livelihoods in Phalombe that had not recovered from earlier storms

The 2023 floods owing to Cyclone Freddy are among the worst to have affected Phalombe. Cyclone Freddy made landfall in Malawi's southern region on March 12, 2023, resulting in severe damage to infrastructure, including roads, buildings, and electricity lines, with the districts of Blantyre, Chikwawa, Chiradzulu, Mulanje, Mwanza, Neno, Nsanje, Thyolo, Phalombe, and Zomba experiencing the greatest impact, leading to the declaration of a state of disaster by the Head of State.[276] Entire villages were washed away during the event due to extensive flooding and mudslides rendering many dead, injured or missing. Figure 1 below shows the impact of cyclone

[274] Steiro, M. (2016). *When the dust has settled: a post-disaster recovery study of water and sanitation reconstruction after the 2015 flood in Phalombe and Nsanje Districts, Malawi* (Master's thesis, NTNU).
[275] Nicholson, H., Chigwenembe, J. and Mc-Colum, D. (2019). The Impacts of Cyclone Idai on Disaster Management in Malawi. University of St. Andrews, Edinburgh.
[276] Tasking Manager (2023). CYCLONE FREDDY, PHALOMBE & MULANJE RESERVE, MALAWI. Accessed at https://tasks.hotosm.org/projects/14482#description

Freddy as reported by the Department of Disaster Management Affairs. The close temporal proximity of these storms has meant that as each storm arrives, because the district has not yet recovered and systems rehabilitated from previous storms, those very same systems are fragile and highly vulnerable, thus loss and damage is compounded.



Map showing flood impact from Cyclone Freddy.[277]

In examining floods as a climate hazard, we note from literature and observations during the community interface that flood vulnerability is closely linked to geography and terrain. The mountainous terrain surrounding Phalombe and its close proximity to Mulanje Mountain create an environment conducive to heightened climate-related risks. The steep slopes prevalent in this region significantly elevate the likelihood of soil erosion and landslides, particularly during periods of intense rainfall, thereby exposing local communities and infrastructure to elevated risks of damage and disruption. This is evidenced by the 1991 disaster that saw entire communities wiped out as a result of floods and landslides (Petzold, 2021).[278] Geological and biological fauna evidence suggest that Lake Chilwa was connected to Lakes Chiuta, Amaramba and the Lugenda River, and ultimately the Indian Ocean until the late Pleistocene.[279] Much of what is now Phalombe District was part of a much larger Lake Chilwa in the past so, essentially stands on a former lake bed.

[277] https://floodlist.com/wp-content/uploads/2023/03/map-of-flooded-areas-in-Malawi-DoDMA-591x1024.png
[278] Petzold, M. (2021). The 1991 Phalombe Disaster, *The Society of Malawi Journal*, 74, 1, 7-11.
[279] Lancaster, N. Formation of the Holocene Lake Chilwa sand bar, *Catena*, 8 369–382.

At the same time, some human-biophysical interactions seem to heighten exposure to floods. For example, participants in the Phalombe Socio-economic Focus Group Discussion (FGD) during the field mission attached to this work conducted during the climate risk analysis cited soil erosion, heavy rains, poor site selection for cultivation land, and poor workmanship for public infrastructural works as possible exposure risk factors for flood hazard. Inadequate land-use choices, particularly in areas prone to flooding, can increase the susceptibility of agricultural livelihoods to flood-related risks during periods of heavy rain or flooding. Soil erosion, often aggravated by substantial rainfall, reduces the land's ability to retain water, increasing the chances of surface runoff and subsequent flooding. Additionally, deforestation can worsen such scenarios by diminishing the land's capacity to absorb water. On the technical side substandard construction practices and insufficient maintenance of public infrastructure, including drainage systems, can further worsen flood hazards when these systems prove inadequate in managing heavy rainfall and floods.

b. Droughts and Dry Spells

Droughts and dry spells have been a recurring feature in Phalombe's climate history. One of such drivers in the natural variation between the La Nina and El Nino cycles of the ENSO alternating between 4-7 years. While droughts and dry spells have been part of the region's historical climate, the impact and frequency may be changing due to the effects of global climate change, which has added new layers of complexity to the challenge. Droughts are seen to be more adverse due to their widespread nature when they eventually occur. Drought is officially declared in the country when seasonal rainfall falls below 75% of the normal, and dry spells, frequently evolving into droughts, typically persist for 3 to 4 months within the rainy season in many regions of the country (Chabvuma et al, 2014).280 Hydrological drought expresses deficiencies in surface and subsurface water supplies while meteorological drought expresses precipitation's departure from normal over some period of time (GoM, 2016).[281]

In 2002, Malawi faced a severe drought with extensive crop failures, food shortages, and a humanitarian crisis that also affected Phalombe. Similarly, the years 2005-2006 and 2012 also witnessed dry spells and irregular rainfall, affecting crop production and food security in various regions of the country. The most notable recent drought event to have affected Phalombe occurred in the 2015-2016 rainfall season. Marked by a potent El Niño event, this drought brought about prolonged dry spells and irregular rainfall, predominantly affecting the southern and central regions of Malawi. Crop production, particularly of the staple maize, was severely hit, triggering food shortages and soaring prices, adversely impacting the food security of numerous households. Evidently, drought impact is worsened in the absence crop diversification and diversified income sources.

c. Projections brief

As part of the background research for this CRA, the Malawi Department of Climate Change and Meteorology (DCCMS) conducted research into the likely evolution of climate in the country over the 21st century.[282] Rainfall in Phalombe District shows little overall change up to the end of the century although variability is likely to be high. Meanwhile, the wet season appears to be very slowly shortening, by 3-4 days by the end of the century.

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[280] Chabvungma, S. D., Mawenda, J., and Kambauwa, G. (2014). Drought conditions and management strategies in Malawi.
[281] Government of Malawi (2016). Droughts Post Disaster Needs Assessment. Department of Disaster Management Affairs, Lilongwe.
[282] DCCMS (2023)

Rainfall events of over 100mm in 24 hours are, however, likely to increase substantially, suggesting that rainfall will become more intermittent and that there will be more occurrence of heavy storms engendering floods and associated loss and damage.

Commenté [LP90]: Could you please indicate in a footnote the numbers behind "increase substantially"

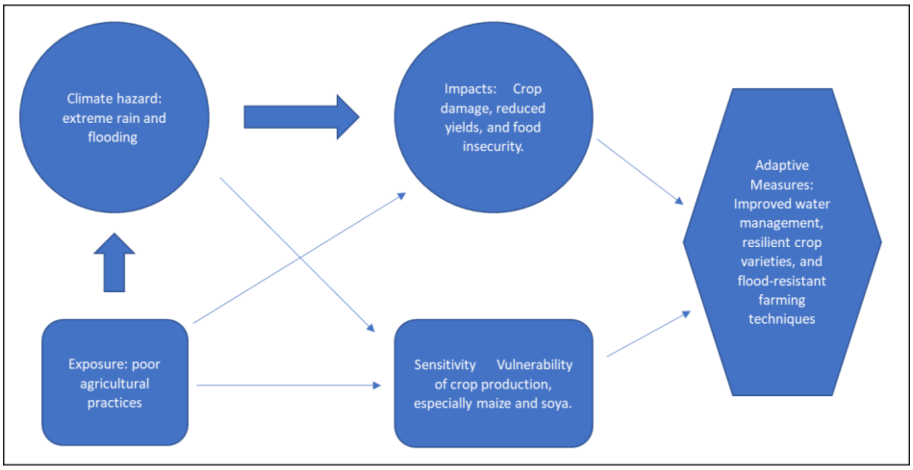
The standardised precipitation index (SPI) intensity used as the proxy for drought intensity, which is supplied by DCCMS for the Blantyre ADD of which Phalombe District is a part, like overall rainfall, also shows little change for the rest of the 21st century. Even if this were to be the case, the history of drought to date shows that risk of drought of great intensity will remain high.

The projections on temperature are, by contrast, much clearer with all models predicting increases in mean annual temperature of between 2 and 3 degrees (mean annual rise) from the average temperature during the control period (1991 to 2020) by the end of the century. Both mean maximum and mean minimum temperatures are showing signs of increasing, both most particularly in the traditionally hot season -October and November and thru the rainy season to January. These increasing temperatures are crosscut by increasing likelihood of temperature extremes. Increasing temperatures put pressure on ecosystems and on social processes and the water budget as will be described in the next section.

4. Sectoral Implications from Climate Hazards on Phalombe

a. Agriculture

The sectoral impacts of drought on agriculture are primarily linked to the direct consequences identified during the focus group discussions, with crop loss being the primary and most significant impact. The recurrent floods that accompany drought events often affect agricultural fields, leading to the sweeping away of crops, rendering them unusable. In cases where crops manage to survive the flooding, the floodwaters leach away essential nutrients naturally present or provided through supplemental fertilizers, leaving behind sandy deposits deposited by the receding water.



Climate Risk Analysis for Agriculture

Over the years, these floods have become particularly problematic, as they may occur outside of the expected rainy seasons when crops are nearing full maturity. Any adverse event at this stage can lead to the destruction of a substantial investment made by farmers. This immediate consequence strikes at the heart of Phalombe's agrarian economy, disrupting the livelihoods of countless farmers who depend on their harvests for sustenance and income. Simultaneously, domestic food needs for the entire year are severely compromised, as the loss of crops translates into a food shortage within the district.

As previously outlined, crop loss leads to reduced access to staple foods, including maize and other dietary essentials, posing a critical challenge for households and making it increasingly difficult to secure adequate sustenance. In 2019, flood damages affected a total of 91,637.53 hectares of land used for crop cultivation across the country, with 17,774.4 hectares of this impact occurring in Phalombe.[283.] The district recorded extensive flood damage, accounting for 8.1% of the overall impact on agricultural systems. Crop damage occurred over an area of 2,996 hectares in Phalombe, with the district also recording a 19% share of the total maize damage during another episode of extreme flooding.

b. Health

Disasters in Phalombe, such as floods, droughts, and extreme weather events, have multifaceted impacts on the life and health of the local population, with death and injury being key consequences. One of the immediate health issues stemming from these disasters is food insecurity and water scarcity. The disruption of food supply chains and contamination of water sources can lead to significant health problems. Insufficient access to an adequate and nutritious diet contributes to malnutrition, affecting children's cognitive and physical development. Female-headed households, in particular, are vulnerable to poor food consumption during climate extremes, with Phalombe recording over 40 percent reduction in adequate food consumption among such households in 2016. Moreover, reduced forestry products, including thatching grass, wood, mushrooms, and wild fruits, further exacerbate food and livelihood challenges due to temperature increments.

Disasters also have a profound impact on mental health. The stress and anxiety resulting from the loss of homes, crops, and livelihoods, as well as the uncertainty and fear associated with disasters, can contribute to mental health challenges. These issues not only affect the well-being of individuals but also have broader societal implications, including conflicts and migration. The disruption caused by disasters affects productivity and increases vulnerability, particularly among certain populations. As the climate becomes more unpredictable, the social and mental health implications of these disasters are becoming increasingly apparent, necessitating a comprehensive approach that addresses not only immediate relief but also long-term mental health support for affected communities.

c. Fisheries

The impact on capture fisheries and aquaculture is mainly due to flooding. Lake Chilwa's water level has been fluctuating significantly over the years due to climate change factors such as changes in rainfall patterns, and human activities such as dam construction, and overfishing or fishing with inappropriate equipment such as mosquito nets which extract even the smallest fish and crustaceans from the lake. These fluctuations have had a significant impact on the fisheries and aquaculture industries in the area. When the lake's water level is high, it can lead to flooding of nearby areas, including fishponds and fishing grounds. This can result in the loss of fish stocks and damage to infrastructure, leading to economic losses for local communities.

[283] Government of Malawi (2019). 2019 Floods Post Disaster Needs Assessment Report. Department of Disaster Management Affairs.

Conversely, droughts seriously disrupt water availability in quantity and quality. During droughts, much of the water budget is lost through evapotranspiration and reduced flows into water bodies resulting in low lake levels (with Lake Chilwa increasingly drying up completely), and reduced river flows. Ecological changes in the marine ecosystem pose a threat of decline in fishery resources. Depletion of fish-stock and reduction in fish production could threaten the livelihoods of many vulnerable fisher communities and the food security of many countries in Sub-Saharan Africa.[284]

Depleting water levels and the drying of fish ponds serve as critical indicators of aquaculture system challenges. Notably, in 2016, the drying of the lake resulted from the interplay of changing climatic conditions and natural hydrological variations, leading to a significant reduction in fish species availability and production within the district. Estimated losses amounted to 1.92 billion Malawi Kwacha.

Number Of Ponds Dried Out	Total Pond Area (Square Meters)	Quantity Of Fish Lost (Kg)	Estimated Value Of Total Loss Of Fish (MWK)
21	1,282,640.00	1,282,640.00	1,924,737,000

Source: Government of Malawi Droughts PDNA 2015-2016

Additionally, government reports in 2022 indicated a general upward trend in average beach prices for Phalombe, Machinga, Zomba[285,] Karonga, and Rumphi in 2021 compared to 2020, with the highest beach prices recorded in Phalombe at MK1,861 per kilogram of fish.[286]

The water levels of Lake Chilwa have experienced notable fluctuations over the years, influenced by various factors such as shifts in rainfall patterns, human activities like dam construction, and the overarching impact of climate change. These fluctuations have significant implications for both capture fisheries and aquaculture industries in the region. When the lake's water level rises, it can result in flooding of adjacent areas, including fishponds and fishing grounds. This inundation leads to the loss of valuable fish stocks and also causes damage to critical infrastructure, which, in turn, results in substantial economic losses for local communities.

Moreover, the fluctuating levels of Lake Chilwa are not the only concern. When the lake's water level rises, it can also trigger increased sedimentation and nutrient loading. These phenomena adversely affect the lake's aquatic life, potentially harming fish populations and the broader aquatic ecosystem. This dual impact of fluctuating water levels and pollution further underscores the challenges faced by the region's fisheries and aquaculture sectors, which are critical sources of livelihood and sustenance for local communities.

d. Infrastructure Development

Disasters, including flooding and extreme weather events, have significant sectoral impacts on infrastructure development in Phalombe. One key challenge is the prevalence of poor workmanship for public infrastructural projects, often stemming from a lack of skilled labour and limited resources available for constructing vital infrastructure such as roads, bridges, and buildings. This can result in

[284] Mohammed, E. Y., & Uraguchi, Z. B. (2013). Impacts of climate change on fisheries: Implications for food security in Sub-Saharan Africa. *Global Food Security, Nova Science Publishers, Inc*, 114-135.
[285] Government of Malawi (2022). ANNUAL ECONOMIC REPORT 2022. Ministry of Finance and Economic Affairs, Lilongwe.
[286] https://psip.malawi.gov.mw/reports/docs/Economic_Report_2022.pdf

subpar construction quality, leading to structural weaknesses and safety hazards as evidenced by the extensive damage caused by the 2023 Cyclone Freddy floods.[287]

Additionally, the impact extends to housing structures, as many homes are constructed without proper storm-water management systems due to economic constraints. This lack of adequate drainage infrastructure can lead to flooding and waterlogging during rainfall, causing damage to homes and other structures. Moreover, it fosters an environment conducive to the spread of diseases like malaria and cholera. Inadequate drainage systems further exacerbate the vulnerability of both public and residential infrastructures to the adverse effects of disasters in the region.

Furthermore, flood damages extend to the water, sanitation, and hygiene (WASH) sub-sector. For example, floods that occurred in Phalombe in 2019, resulted in estimated losses of 0.79 million USD. These damages included the destruction of infrastructure such as boreholes and piped water supply systems, many of which were washed away by the floods. The impact on the water resource sub-sector alone was assessed at 0.13 million USD according to the 2019 Floods Post-Disaster Needs Assessment (PDNA).

e. Energy

Disasters, such as floods, droughts, and extreme weather events, exert a pressure on energy access in Phalombe District. This starts off as an extension to infrastructure damage, leading to power outages and diminished electricity accessibility for both residents and businesses. Floods, in particular, inflict physical damage on power lines, transformers, and substations, hindering the delivery of electricity services. The implication of this occurrence spreads to other sectors of the economy including health, trade and agriculture. On the flip side, the increasing occurrence of such disasters has implications on availability of biomass-based fuels either due to drying or loss from flood events. The demand for these types of fuels – charcoal and wood fuel – already high as most people do not have access to electricity, increases when power fails. The Lake Chilwa Basin is not replete with trees therefore the pressure to strip forested hillsides on the Mulanje Massif and the Mchese Forest Reserve, to the south of the district, increases exponentially at times of energy crisis which occur every time a climate or weather disaster occurs.

f. Risk summary

Phalombe District is one of the most affected and vulnerable districts in the country to the negative impacts of climate change and extreme weather. The high density (370 per km^2)[288] and poverty of the population in the district, which is almost wholly rural and low levels of infrastructure such as roads, bridges and public buildings leave this district highly exposed. The combined impacts of storm and flood events from 2015 to 2023, have left livelihoods such as agriculture and fishing, in a precarious condition. Climate projections indicate that, if anything, extreme weather events (storm/flood/drought) will increase in frequency and intensity. Risk in Phalombe District consists of low resilience and management capacity when disaster strikes, fragility of the population to recover from disaster, low institutional capacity, with communities reporting low levels of extension and lack of capacity and resources at district council leadership level and lack of adaptation strategies to support local communities to protect lives and strengthen and diversify livelihoods in the face of predicted climate change.

Commenté [J[91]: Does the high density refer to poverty or distribution of people? I read it as density of the people but then it says its a mostly rural district, so this is a little confusing

Commenté [LF92R91]: As has been observed, Phalombe District is mostly rural but has a remarkably high density of population which I observed during field visits en-route to Lake Chilwa and is, concomitantly, very poor and very vulnerable and exposed. As the leader of a Beach Village Committee replied to me with irony when asked about emergency shelters when floods arrived this year, 'We have nowhere to run to, we receive occasional visits from big people who brave that track to come to have meetings with us and make big promises about help, even to get that road fixed, then we do not see them again. Nothing ever gets fixed here. The extension officers have no money; we have no money. Yet more and more people come to share our land and few resources. If we leave to look for shelter when the flood comes or the lake dries up, all that will happen is that someone else will run to take our places.'

[287] See Inception Impact Storylines Report Annex 1

[288] https://malawi.places-in-the-world.com/1105842-region2-phalombe-district.html#google_vignette

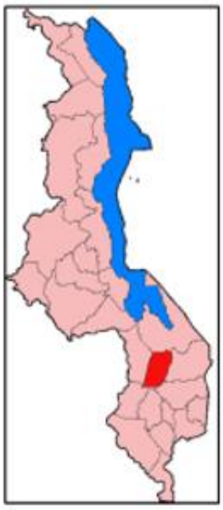
Annex 3: Balaka District – Climate Risk Assessment Report

Commenté [LP93]: Same comment as for Chikwawa, could we have a risk summary section?

Commenté [LF94R93]: Done

Commenté [LP95]: And across all annexes, refer to the field mission when relevant?

1. Introduction



As climate change continues to affect global weather patterns, the implications for Balaka district are becoming increasingly apparent. Climate resilience has become a top priority for many communities as they grapple with the escalating impacts of climate change that presents many challenges for major components of the social economy. This Climate Risk Assessment (CRA) report delves into the various aspects of Balaka's vulnerability to climate-related hazards and their impact, dissecting the intricate interplay between environmental factors and their impacts on livelihoods, agriculture, infrastructure, and overall community well-being. This report is informed by findings from literature as well as the discussions from climate risk analysis focus groups conducted in Balaka as part of this CRA.

2. Local Climate and Weather in Context

Balaka, situated in the southern region of Malawi, East Africa, is located between 14.9861° S latitude and 34.9443° E longitude. It is bordered by Zomba to the north, Machinga to the northeast, and Phalombe to the south, all these being part of the Lake Chilwa Basin. The local climate is shaped by this proximity and the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ) which is a major weather system influencer for Malawi.

Balaka generally experiences a humid subtropical climate (classification Cwa under the Köppen-Geiger climate classification system),[289] characterized by well-defined wet and dry seasons. The wet season typically runs from November to April as the ITCZ shifts southward, bringing moisture-laden air. This season is crucial for agriculture, supporting crop cultivation and refilling water resources. The following months form the cool dry seasons (May to July) and hot dry seasons (August to October) respectively. In these months, water is not as available for domestic and agriculture functions underscoring the significance of the seasonal climate patterns for local livelihoods.

With regard to the local temperature, Balaka experiences consistently warm to hot conditions throughout the year. Average temperatures can range from approximately 20°C to 30°C between cooler and warmer months with occasional heat waves occurring during the hot and dry months, the district's proximity to Lakes Malombe and Chilwa may at times result in local weather changes from increased humidity. All these variations in Balaka's climate have profound implications for agriculture, water resources and livelihoods, especially in the context of a changing climate.

3. Geography and Demographic Characteristics

Balaka district covers area of 2,193 km.² and has a population of 590,131 people and 128,685 households.[290] As with many other Malawian districts, the population is made up of quite a number of smallholder farming families. Maize the country's main staple crop is grown in the district either as a

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[289] Source: Nomad season (2022). Monthly climate in Balaka, Southern Region, Malawi https://nomadseason.com/climate/malawi/southern-region/balaka.html

[290] National Statistics Office (2019). National Population and Housing Census. NSO, Zomba

solo crop, but is sometimes intercropped with legumes such as cowpeas, pigeon peas and groundnuts. Tobacco, cotton, cassava and many other horticultural crops are also grown. While a considerable segment of the population remains engaged in subsistence farming, there is an emerging trend towards small-scale commercial agriculture, marked by the cultivation of cash crops and the marketing of surplus agricultural products. In addition to this, small and medium enterprises significantly contribute to the district's economic landscape. The labor force is diverse, incorporating individuals involved in a wide spectrum of occupations, including agriculture, commerce, education, and various service industries.

4. Hazard Mapping

Four hazards, namely storm, floods, drought and extreme heat were identified to be at the core of the districts hazard focus. Each of these are discussed at length as follows.

a. Storm

A recurring trend has been observed over the last few years posing significant threat on the resilience of lives and livelihoods. Storms occur either due to the usual torrential rains or as a residual impact from tropical cyclones that are formed in the Mozambique Channels but make landfall in nearby regions seeing that Malawi is landlocked. Often times, these storms are accompanied by heavy rains and winds that expose the agriculture system to significant harm. These also have an implication on housing and infrastructure development due to the exposed risk to flooding and its consequential damage.

For the agricultural sector, storms have been seen to affect crop growth and development, as well as to devastate the functionality of agricultural systems, irrigation systems inclusive. Maize and soy bean, which are among the primary crops cultivated in the area are most affected. The strong winds and heavy rainfall associated with storms can physically damage soybean and maize plants. Strong winds have the potential to break stems and uproot plants, while excessive rainfall in itself can lead to waterlogging, causing root rotting as both plants are not easily adaptable to excess water. This can result in reduced crop yields or even complete crop loss. At the same time, many of these storms occur at critical development seasons, and in some cases, replanting cannot be done.

Given that agriculture is a cornerstone of the district's economy and a key source of livelihood for many residents, these storm events can have far-reaching socioeconomic consequences. As a result, farmers face substantial yield losses, and the food security of the local population is compromised. A profound example of such an event is the 2018 storm event that struck most parts of Traditional Authorities Kachenga, Msamala, Sawali, and Nkaya in Balaka. A cumulative total of 698 households were critically affected. At the time, the district was already responding to an infestation of Fall Armyworms that affected 19,000 of the 53,000 cultivated hectares of land, representing a total of 39 per cent.[291]

Other impacts of these events are felt in the infrastructure and housing sector. These winds can attain very high velocities, causing extensive damage to both natural and built environments. As with many other parts of Malawi, the housing system is fairly traditional, comprising of grass thatched roofing in many cases and unburnt bricks. In the incident that these storms occur, houses are subject to falling from the excessive moisture, or roofs easily blown off. Cyclone Freddy that hit Malawi in February 2023 left many parts of Southern Malawi greatly devastated is reported to have damaged over 80 houses,

[291] Source: Government of Malawi (2018). Double tragedy in Balaka: rainstorms; fall armyworms cause havoc. Accessed from: https://reliefweb.int/report/malawi/double-tragedy-balaka-rainstorms-fall-armyworms-cause-havoc

living two dead[292]. Similarly, 3 were reported dead in the January 2019 storm that affected parts of Mangochi and Balaka[293].

Other forms of infrastructure, especially roads, bridges, water supply systems and social-service infrastructure are left exposed; compromising transportation, communication, and access to essential services. The consequences of such storm-related destruction ripple through the community, posing considerable challenges for disaster response and recovery efforts.

b. Floods

The immediate aftermath of such storm events is flooding. Floods, whether caused by heavy rainfall (pluvial) or river overflow (fluvial), pose several critical challenges depending on the extent and intensity of occurrence. Floods in Balaka have occurred as part of widespread flooding like the 2015 national floods that affected 25 of 28 districts (Tropical Storm Chedza),[294] the 2019 Cyclone Idai floods that affected 15 of the 28 districts295, and the 2022 Cyclone Ana floods.

Before floods can affect productive systems, they first pose a threat to human life and can inflict various forms of harm, injury and even death from the velocity of flood waters. This impact is grave in the absence of early-warning systems and well-organized civil protection structures in the community. Various forms of water-borne diseases ensue as water that is abundantly present is not safe for domestic functions. As some flood incidents are not predicted as quickly, they may find health systems unprepared or unable to adequately respond to emergencies.

In an attempt to safeguard life, families that are displaced by floods are placed in camps. Although this is beneficial for the overall welfare of the people, other sectors such as education, energy and trade are affected. Camps that are used for the purpose of evacuation are often sites like schools, such that teaching and learning is disrupted. For example, the 2022 floods caused by cyclone Ana affected 476 schools in 22 Education districts of Malawi including Balaka.296 While the 2015 floods cost Balaka's education system about $300,000.[4]

The agriculture sector is a significant priority area to be addressed in regards to flood occurrence. These events notably affect riverine agriculture and encompass a spectrum of consequences, including crop damage, livestock losses, water contamination, and soil erosion. Maize, the main staple crop is water sensitive, heightening the potential of crop damage. At the same time, soy-bean does not perform as well as it should when water is in excess. Waterlogged conditions can lead to mould and mildew growth on the pods, potentially rendering the soybeans unsuitable for human or animal consumption.

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[292] Malawi 24(2023). Cyclone Freddy: Two injured, over 80 houses damaged in Balaka. Accesed from: https://malawi24.com/2023/03/15/cyclone-freddy-two-injured-over-80-houses-damaged-in-balaka/
[293] Source: Government of Malawi (2019). Three die in recent Mangochi, Balaka disasters. https://reliefweb.int/report/malawi/three-die-recent-mangochi-balaka-disasters
[294] Government of Malawi (2015). Floods Post Disaster Needs Assessment Report. Department of Disaster Management Affairs, Lilongwe
[295] Source: Real-Time Response Review – DEC programme for Cyclone Idai: Malawi country report. Accessed from https://reliefweb.int/report/malawi/real-time-response-review-dec-programme-cyclone-idai-malawi-country-report#:~:text=Nine%20DEC%20members%20responded%20to,the%20central%20part%20of%20Malawi.
[296] Source: Department of Disaster Management affairs (2022). Situation Report: Cyclone Ana. Accessed from: https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/situation_report_15feb.pdf

c. Extreme Heat

Extreme heat is yet another significant climate hazard in Balaka, and its adverse impacts reverberate across multiple sectors, including agriculture and fisheries. During the hot and dry months, temperatures as high as 41 degrees Celsius have been recorded in Balaka District, causing considerable damage to crucial crops, particularly maize and soybeans. Episodes of extreme heat contribute to moisture stress in crops limiting certain vital processes from taking place, ultimately leading to yield reduction, thereby affecting the livelihoods of many residents and undermining food security. With maize and soybeans being major food and cash crops, the significance of this climate hazard is huge. Livestock also bears the brunt of such heat waves. Primarily, pasture and water are available in lower levels as a result of drying. Animal nutrition is compromised causing lower animal productivity. The combination of these two has a bearing on human nutrition and the cost of food.[297]

d. Drought/Dry Spells:

Malawi is influenced by the El Niño Southern Oscillation (ENSO) phenomenon. The ENSO phenomenon has alternating cycles of El Niño and La Nina events. El Niño events, characterized by warmer sea surface temperatures in the equatorial Pacific Ocean, often result in drier conditions and droughts in many parts of Malawi. The change in global climate patterns, including rising temperatures and changing rainfall patterns, has led to increased occurrences of drought. The 2023-2024 rainfall season is expected to be influenced by moderate to strong El Nino which is associated with moderate to extremely high temperatures.

5. Future climate hazard risk

As part of the background research for this CRA, the Malawi Department of Climate Change and Meteorology (DCCMS) conducted research into the likely evolution of climate in the country over the 21st century.[298] Rainfall in Balaka District shows little overall change up to the end of the century although variability is likely to be high. Meanwhile, the wet season appears to be very slowly shortening, by 3-4 days by the end of the century.

Rainfall events of over 100mm, 120mm and 150mm in 24 hours are, however, likely to increase sharply (DCCMS (2023), suggesting that rainfall will become more intermittent and that there will be more occurrence of heavy storms engendering floods and associated loss and damage.

The standardised precipitation index (SPI) intensity used as the proxy for drought intensity, which is supplied by DCCMS for the Machinga ADD of which Balaka District is a part, like overall rainfall, shows little change for the rest of the 21st century. This is at variance with the evidence of local people at the Balaka CRA workshop held in July 2023 as part of this task who asserted that the climate has become noticeably drier and with longer, warmer dry spells and that this was affecting livelihoods as much as flooding in the district. Even if this were to be the case, the history of drought to date shows that risk of drought of great intensity will remain high in what is a comparatively dry and warm part of Malawi.

The projections on temperature are, by contrast, much clearer with all models predicting increases, by between 2.45 and 3.45 degrees C (mean annual maximum), between 1.9 and 3 degrees C (mean annual minimum) between 1.8 and 2.8 degrees C (mean annual mean) by the end of the century, from the average temperature during the control period (1991 to 2020). Temperature increases are

[297] DCCMS (2023). BALAKA DISTRICT DOWNSCALED SEASONAL FORECAST, 2023-2024. https://www.metmalawi.gov.mw/docs/district_fcsts/balaka_2324_en.pdf
[298] DCCMS (2023)

predicted for all seasons but most especially in what is already the hot season -October and November when most days of extreme hot weather (above 35 degrees C) are likely to occur put pressure on ecosystems and on social processes and the water budget as will be described in the next section.

6. Climate Impact Analysis by Sector

a. Agriculture

Climate change has exerted a significant impact on the agriculture sector in Balaka, with various climate hazards posing challenges to the region's farming sector. Balaka has faced extremely dry seasons and floods, where 20% of the farming households were affected. As a result, 45% of the population have faced food insecurity.299 Storms characterized by extreme rain and wind, along with floods, both pluvial and fluvial, have been detrimental to crop cultivation in the district. These events have led to crop damage, particularly affecting high-priority crops like maize and soya. The combination of intense rainfall and strong winds intensifies the destructive potential of storms. The damage to crops not only results in yield loss but also contributes to food insecurity, affecting the livelihoods of many residents in Balaka.

Participants from the Focus Group Discussions at the CRA workshop in Balaka in July 2023 agreed that crop failure and reduced harvests have wide-ranging effects that extend well beyond the agriculture sector, profoundly affecting the livelihoods and well-being of Balaka's residents. The immediate consequence of these impacts on agriculture is a heightened risk of food insecurity. With reduced access to staple crops due to poor harvests, families often struggle to secure an adequate and balanced diet leading to malnutrition, particularly for vulnerable groups like children and the elderly. This not only worsens poverty in one of Malawi's poorest districts but creates a platform for other economic challenges and exploitation.300

Furthermore, the high temperatures associated with extreme heat can lead to moisture stress in crops, impacting their yield and quality. In addition, prolonged dry spells and water scarcity due to drought conditions exacerbate the challenges faced by farmers. The stress on livestock due to forage scarcity and reduced availability of water resources further compounds the food security situation. These climate-related challenges have been exacerbated by deforestation, poor soil and water management practices, high reliance on rain-fed farming, and a lack of drought-tolerant crop varieties. A pictorial representation of the impacts of climate change on the agriculture sector is given in the figure below.

Commenté [J[96]: Climate Hazard is here twice - maybe one is supposed to be something else?

b. Forestry and Fisheries

Commenté [J[97]: This section seems general to Malawi but not specific to Balaka

Commenté [LF98R97]: Addressed

In Balaka District, climate change has triggered evident shifts in temperature and precipitation patterns, resulting in prolonged dry spells that intensify forest fires. The risk of a wildfire hazard is classified as high connoting that there greater than a 50% chance of encountering weather that could support a significant wildfire in any given year.[301]

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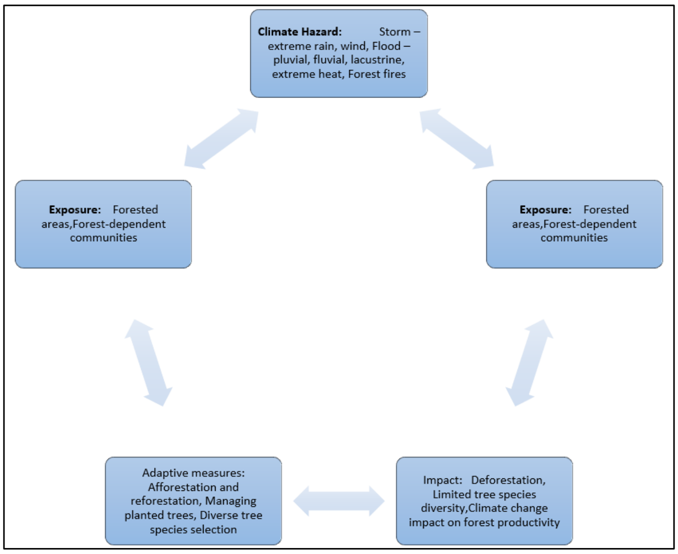
[299] Self Help Africa (2023). Improving food security and economic empowerment for Malawi's smallholder farmers. Accessed from: https://selfhelpafrica.org/ie/improving-food-security-and-economic-empowerment-for-malawis-smallholder-farmers/#:~:text=Balaka%20has%20been%20facing%20extremely,population%20have%20faced%20food%20in security.

[300] Government of Malawi (2016). Drought Post Disaster Impact Assessment Report. Department of Disaster Management affairs, Lilongwe.

[301] Thinkhazard. Accessed from https://thinkhazard.org/en/report/42174-malawi-southern-region-balaka

In a natural set-up, forest fires are vital for nutrient cycling and pest and disease control. However, the increasing frequency infringes on community needs, especially because many communities are dependent on forest resources. According to the Focus Group participants, there has been a noticeable reduction in the availability of essential forest products such as thatching grass, wood, mushrooms, and wild fruits in recent years which many residents rely on for various purposes. As agricultural activities expand to meet the growing food demand, forests are being cleared to give rise to new farmlands. This has further implications for soil and water management, as it reduces the forest's capacity to retain water, exacerbating water scarcity in times of drought.



Climate hazards on the forestry sub-sector.

In the same way, climate change has profound implications on fishing. During periods of increased water levels in Lake Malombe, associated with heavy rainfall events or cyclones and rapid outflow of water from Lake Malawi into the Shire River via Lake Malombe, flooding has submerged fishponds and fishing grounds. This flooding often leads to the loss of fish stocks, intrusion of alien invasive species to ponds and damage to fishing infrastructure. On the other hand, during droughts when the lake's water levels decline, fishing activities become challenging, as the fish migrate to deeper waters or perish due to deteriorating water quality. Likewise, increased sedimentation and nutrient loading during high-water levels have detrimental effects on aquatic life in the lake.

Direct fiscal implications from floods on the fisheries subsector have been moderate for the district. For example, only 2 million Malawi Kwacha was reported as damage to the fisheries sub-sector in 2015 as a result of droughts. However, more harm is observed during drought as evidenced by river and pond drying resulting in lowering fish catch. With river drying comes reduced diversity of fish especially in rivers. The impact of climate change on the fisheries subsector is demonstrated below:

Climate Hazard: Storm, extreme rain, wind, Floods – pluvial, fluvial, lacustrine	**Impact**: Habitat degradation, Pollution
Adaptive measures: Aquaculture practices, Sustainable fishing methods, Habitat restoration, Pollution control	Exposure: Changes in water temperature, Overfishing

Climate hazards on the fishery sub-sector.

c. Social Implications: Gender and Marginalized Groups

Climate change has a gender/social dimension that is often overlooked. Vulnerable groups including women, children, the elderly and those living with disabilities are more exposed than other groups. This may be linked to certain types of disasters, and (or) changes that occur as a result of human-environment interactions in a changing climate. For example, as part of human activities, deforestation has become rampant in the district. From 2001 to 2022, Balaka lost 122 ha of tree cover, equivalent to a 4.5% decrease in tree cover since 2000, and a net gain of 35.3 kt of CO_2e emissions.[302] This presents a new paradigm for energy needs. Culturally, women and girls are responsible for addressing household energy needs, including fetching wood for cooking and heating purposes. What this means is that they have to travel longer distances to access wood, affecting their participation in other socio-economic functions.

At the same time, disaster impact may shape other social interactions. For example, displacement from flood impact may disintegrate the family unit while also exposing women and girls to forms of exploitation as they attempt to access food and other services. In times of food insecurity in Balaka, Malawi, violence against women and girls increases, with acts including spouse physical battery, men abandoning their families in search of employment, sexual harassment and abuse, economic exploitation, and girls dropping out of school to support their households[9].

Similarly, disasters in the form of flood and drought may compromise sanitation due to limited water access affecting menstrual hygiene practices in the process. At the same time, access to certain forms of healthcare, particularly contraceptives and anti-retroviral therapy (ART) may be stopped. It has also been observed that families headed by these marginalized groups are more vulnerable as compared to others. For example, a preliminary report by the Balaka District Council in 2018 following flood

[302] Source: Global Forest Watch. Tree Cover Loss: Balaka, Malawi.

occurrence indicated that 26 families in T.A. Kalembo were displaced, of which 21 were female-headed.[303]

7. Preliminary comments on adaptation - Balaka

Considering the gravity of the implications of climate change on Balaka, resilience building and developing adaptation options is imperative. This can be achieved by addressing the various factors that promote risk and vulnerability, among which are deforestation, poverty and weakening agricultural systems.

Firstly, afforestation of heavily deforested areas and promoting agroforestry presents promising solutions. Agroforestry, in particular, allows communities to diversify their income sources and agricultural practices, making them more resilient to the changing climate. These initiatives can help restore ecological balance, reduce soil erosion, and improve water availability. Furthermore, afforestation and agroforestry initiatives enhance the local ecosystem's ability to withstand the impact of extreme weather events and improve rainfall stability.

The promotion of clean energy technologies, such as cooking gas, addresses energy disparities for women and marginalized groups in particular. Shifting from biomass dependency for cooking not only reduces deforestation and forest degradation but also mitigates indoor air pollution, which is detrimental to human health. Clean energy technologies ensure a sustainable energy supply, supporting households with their energy needs while protecting the environment.

The introduction of carbon markets as an incentive for deforestation and reforestation efforts can have a twofold benefit, sustainable forest management but also encouraging carbon sequestration, thereby contributing to global climate mitigation efforts. Such initiatives can provide employment opportunities in environmentally sustainable sectors like renewable energy, and conservation. These adaptation options collectively reinforce the district's capacity to address climate change impacts while fostering a more sustainable and resilient future for its residents.

8. Risk Summary

As climate change accelerates, Balaka District in Malawi grapples with a myriad of climate-related hazards, posing significant challenges to various sectors and community well-being. The risks are diverse and intersecting, demanding comprehensive strategies for resilience-building. Below are key climate risks identified across different sectors:

Agriculture: Storms and Floods disrupt crop growth and irrigation systems, causing substantial yield losses. At the same time, extreme heat, droughts and dry spells affect crucial crops like maize and soybeans, leading to moisture stress and yield reduction.

Forestry and Fisheries: Forest Fires, intensified by prolonged dry spells, lead to reduced forest resources and soil-water management challenges. For the fisheries sector, fluctuating water levels impacting fish stocks, with both floods and droughts posing challenges to fishing activities.

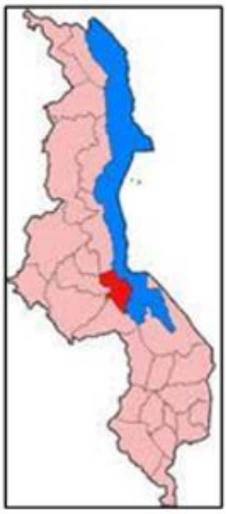
Infrastructure Development: Storms and floods cause extensive damage to roads, bridges, and water supply systems, compromising access to essential services. Inadequate drainage contributes to flooding, fostering disease spread, and hindering disaster response in the process.

[303] Source: ReliefWeb (2018). Flash floods displace 26 families in Balaka. Accessed from: https://reliefweb.int/report/malawi/flash-floods-displace-26-families-balaka\

Social Implications (Gender and Marginalized Groups): Climate change disproportionately affects women responsible for household energy and water needs. Limited water access during extreme climate events impacts hygiene practices and healthcare access for these groups.

Annex 4: Salima District – Climate Risk Assessment Report

Salima District is located in the Central Region of Malawi, along the shores of Lake Malawi. It covers an area of approximately 2,196 square kilometers, an estimated population of over 350,000 people. The population is diverse, with various ethnic groups and cultures coexisting. Salima is known for its beautiful lakeshore scenery and for serious poverty in the rural hinterland inland from the lake. It is bordered by Lake Malawi to the east, bordering the beautiful lakeshore, and is surrounded by other districts including Nkhotakota to the north, Dedza to the south, and Lilongwe and Dowa to the west.



1. Climate

Salima has a tropical climate. The temperatures in Salima generally range from 18°C (64°F) to 30°C (86°F) throughout the year and at times gets hotter to around 38°C inOctober and November especially along the lake shore areas. The district experiences a wet season from November to April and a dry season from May to October with annual rainfall varying from 800mm to 1,400mm with the coastal zone attracting the highest totals. Occasional long dry spells occur during the dry season, affecting agriculture.

2. Social Economic Status

Salima is known for its vibrant fishing communities along the Lake Malawi shore, which significantly contribute to the local economy.

Agriculture, including crop cultivation and livestock farming, is a major source of livelihood for many communities.

Tourism is also an emerging economic activity due to the district's proximity to Lake Malawi and its natural beauty.

3. Major Climatic Events

Like many parts of Malawi, Salima has experienced its share of climate-related challenges. Irregular rainfall patterns, droughts, and flooding can impact the district's agricultural sector and the livelihoods of its residents.

The El Niño and La Niña phenomena have sometimes resulted in extreme weather conditions, affecting the region.

Overall, Salima District, with its stunning lakeside location, diverse population, and varied economic activities, plays a vital role in the social and economic fabric of Malawi. While it faces climate-related challenges, its natural beauty and the resilience of its people contribute to its significance in the country's Central Region.

4. Changing weather and climate patterns

Feedback from the FGDs confirmed that that there have been noticeable changes in weather and climate patterns in Salima District. Heavy rains and strong winds, floods, extreme temperatures and drought / dry spells were mentioned as the major hazards experienced in the district.

a. Heavy rains

These have been common in Salima over the years destroying both road and building infrastructure apart from causing floods. In most cases the heavy rains are associated with strong winds: which have damaged and destroyed infrastructure in areas such as Limbi, Kambalame, and Salula villages in Salima. Schools, homes, and farms are particularly affected. The frequency of these strong winds termed "*mwela*" has impact on fishing and therefore affects the fishing communities in the district by causing strong water currents and disturbing fishing.

b. Floods

Floods are devastating Salima District with huge loss and damage to property, and to lives and livelihoods. The floods are common in low lying areas of the district especially along the shores of Lake Malawi and as a result of siltation of the Lilongwe/Linthipe River network that flows through the district. Besides, fluvial floods have increased markedly in places like Salima Town as a result of blockage of the drainage system, also due to the aforementioned siltation and due to poor town planning.

c. Extreme temperatures and heatwaves

There have been cases of extreme heat and heat waves more pronounced compared to the past 3 to 4 decades. This warming has brought cases of drying up of wetlands, crop damage and dying up of wells and surface water bodies dry up impacting winter cropping as well as fish farming in ponds. Extreme heat has also brought negative health outcomes to vulnerable people.

d. Dry spells and drought

Dry spells lasting over three weeks are now frequent, severely damaging crops, drying up of fodder lands, leading hunger, loss of fish due to drying fish ponds, loss of fishing grounds and loss of animals304. The unfortunate part of the dry spells is that they appear during the reproductive stages of the crops.

5. Projections Brief

Commenté [LP99]: In all annexes, would it be possible to have the projections brief done as a map? Just an idea, I wonder if that would be feasible and readable. It would be great if we could also have a map summarising the main features of the risk projections

Commenté [LF100R99]:

As part of the background research for this CRA, the Malawi Department of Climate Change and Meteorology (DCCMS) conducted research into the likely evolution of climate in the country over the 21st century.305 Rainfall in Salima District shows little overall change up to the end of the century although variability is likely to be high. Rainfall distribution over Salima shows that the months from December to April are the wet months with most of the rainfall falling between January and March. The trend analysis indicates positive trend during the rainfall season and negative trend during drier months, suggesting that the rainy season will get wetter and the dry season drier. Meanwhile, the wet season appears to be very slowly shortening, by a couple of days by the end of the century. Whilst the projections for future rainfall are unclear in this study, other studies have projected a clear reduction in mean annual rainfall by mid-century (2040-2069 compared with control period 0 1980-2010 (1021.5

[304] https://www.coopi.org/en/project/strengthening-resilience-of-vulnerable-communities-in-the-salima-and-mangochi-districts.html accessed on 28th October 2023
[305] DCCMS (2023)

mm to 905.4 mm), with substantial reductions in November and December and with confirmed drying in the dry season months, suggesting the district will become parched during the winter season.[306]

The data presented for rainfall events of over 100mm, 120 mm and 150mm in 24 hours seems not to offer a reliable projection for the future, therefore has to be ignored. Therefore, it is not possible to comment on the likely distribution of rainfall in the future in this district.

The standardised precipitation index (SPI) intensity used as the proxy for drought intensity, which is supplied by DCCMS for the Salima ADD of which Salima District is a part, like overall rainfall, also shows almost no change for the rest of the 21st century. Even if this were to be the case, the history of drought to date provided by respondents at the CRA workshop in Salima shows that risk of drought of great intensity will remain high.

The projections on temperature are, by contrast, much clearer with all models predicting increases in mean annual temperature of between 1.8 and 2.7 degrees C (mean annual rise) from the average temperature during the control period (1991 to 2020) by the end of the century. Both mean maximum and mean minimum temperatures are showing signs of increasing, both most particularly in the traditionally hot season -October and November and thru the rainy season to January. These increasing temperatures are crosscut by increasing likelihood of temperature extremes. Increasing temperatures put pressure on ecosystems and on social processes and the water budget as will be described in the next section.

The large increases in temperature in the months of October–November will increase crop water demand and evapotranspiration losses of water from agricultural soils, especially if this coincides with reduced rainfall for the same months. This effect is likely to increase the risks of crop failure as a result of inadequate or erratic rainfall during the establishment of rainfed crops. Furthermore, the increased average temperatures are likely to include increased frequency or severity of heat waves and unusually hot days, further contributing to evapotranspirative losses of water and crop stress.[307]

6. Climate risk assessment (CRA) – impacts and vulnerability analysis

Climate risk is the potential for climate change to create adverse consequences for human or ecological systems. This includes impacts on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services provision, ecosystems and species.

High risk is defined as a situation where the exposure to climate hazards is high, the sensitivity of the system is high and the adaptive capacity is low.

Commenté [J[101]: It depends on the scale utilized, for example high sensitivity combined with medium exposure and low adaptive capacity is still high risk

On the other hand, Climate Risk Assessment (CRA), follows an impact assessment approach: hazard-driven and focuses on the impacts of climate change in a specific area or collection of assets. The assessment considers, for example, the risk of drought to food production in a set of regions.

A CRA workshop for Salima district was therefore conducted on Tuesday 25th July 2023 at the Kabumba Hotel, Lifuwu village area, 25 km northwest of Salima Town. A field mission took place Monday, 24th July, to a group of Village Development Committee members who met at Chikaunga Village area, off the M5 road leading north out of Salima. The following were the outcomes based on four climate Change Hazards, drought (dry spell), extreme temperature, floods and heavy rains and strong winds.

306 https://www.ifad.org/documents/38714170/42164624/climate_analysis_malawi.pdf/89454253-8418-fe90-aa77-78aa82401557?t=1606831139000
307 Ibid

a. Heavy rains and floods

Flood is one of the hazards impacting development in the district causing huge losses to property, and life in some cases. The floods mostly occur as an aftermath of heavy rain. For the past three years, the district has been heavily affected due to La Nina conditions that brought about cyclones such as Cyclone Freddy in 2023, Cyclones Ana and Gombe in 2022, Cyclone Idai in 2019 and Cyclone Chedza in 2015. Flatness or low lying of the areas especially along the lakeshore and poor drainage systems in Salima town exacerbated the flood conditions and impacts. Meanwhile, siltation of the outflow areas of the Lilongwe/Linthipe rivers which flow through Salima town shortly before emptying into Lake Malawi block river channels and cause unprecedented overbanking of floodwater into town and district.

The impacts are presented based on the priority areas, Crop production, Fisheries and aquaculture as well as livestock production.

a. Crop production

Commenté [J[102]: Could these possibly be presented in a table with the crop production, etc down the vertical and the different factors along the horizontal.

Floods cause crop damage, as crops are either washed away, submerged and waterlogged, or the fertile top soils are washed away leaving behind no nutrients for the proper growth of the plants. The results of crop damage are that there are low crop yields due to rotting of crops. This leads to increases in food prices as the supply is low due to reduced yields while demand increases as farmers are unable to feed their own families. Consequently, this leads to food insecurity, an increase in malnutrition due to scarcity of food, Increase in crimes of theft as individuals have no food and income to provide to their families and finally low income and changed moral behaviour as individuals do transactional sex to get food and money to feed their families.

<u>Vulnerability factors</u>

These are anthropogenic activities that enhance the gravity of the impacts. For each sector and climate impacts, there might be different or similar vulnerability factors as per the discussion with the participants. Participants mentioned the following as vulnerability factors.

Deforestation: since trees cover up the ground and enhance infiltration of rain water, absence of trees means increased runoff and accumulation of waters in the low lying or flat areas causing floods. Besides this, cultivating along the flood prone areas as this exposes the crops to any slight flooding that may occur when, if the crops were grown in upland areas away from the flood prone areas, there would be less loss and damage but these more secure lands are the more expensive and out of reach of the poorest subsistence farmers, of whom there are many. In addition to this, it was reported that poor farmers are often paid to farm vulnerable riverside land by richer people based in faraway places like the capital Lilongwe, even though they know this to be an inappropriate and risky activity. Finally, poor agricultural practices including farming without making ridges, making ridges along the slope, no contour bunds to control floods, cultivation along river banks, vulnerable to overbanking that enhance soil erosion, whilst cultivating and clearing of the buffer zones or strips were mentioned.

<u>Exposure factors</u>

The major exposure factor for Salima district is the terrain of the land as most of the floods occur in the flat, largely treeless areas along the lakeshore. Others included the poverty levels of people that enhance the impacts, and prevalence of sickness, elderly and disabled. Another huge exposure factor is the density of population, especially in remote rural areas where there are no tarred roads and little transport.

Adaptation measures

Communities are engaged in afforestation, forestation and tree regeneration initiatives as a way of bringing back the forest covers. They are also engaged in proper land use practices where floodplains are used for crops such as rice.

Capacity required

Members proposed provision of tree seedlings initiative, training in Crop management, training in proper land use and enforcement of penalties on those that do not adhere to the rule and regulations as areas that need to be enhanced if climate change impacts have to be contained.

b. Livestock production

Primary impact

Floods render Loss /Death of Livestock. This is because either the animals are washed away, drowned, or pasture and fodder is damaged leaving the animals that have survived without feed and some of them dying or they die due to sicknesses following increase livestock diseases due to conducive environment for pathogen breeding. The loss of livestock brings low consumption of animal meats as many animals have died or been washed away, increase in poverty as many that depended on livestock cannot find alternative source of income. Increase in transactional sex in search of food and Income.

Vulnerability factors

The following vulnerability factors were mentioned; Deforestation; since trees anchor the soils, leaving the soils bare exposes the soils to flooding, raising animals along the flood prone areas; as this exposes the crops to any slight flooding that may occur than if the crops were grown to upland areas away from the flood prone areas.

Exposure factors

The major exposure factors included Terrain of the land as most of the floods occur in the floods occur in the flat areas. Poverty levels of the people will enhance the impacts as people cannot construct good animal housing or get better land in the upland.

Adaptation measures

Communities are engaged in afforestation, forestation and tree regeneration initiatives, proper land use practices exercises as adaptation measures. But these are only peripheral in assuaging the effects of climate change and extreme weather

Capacity required

Members proposed that Government must initiate provision of tree seedlings, communities to be trained in proper livestock management, Government to provide seed money for diversification of IGAs.

c. Fisheries and aquaculture

Floods cause siltation of the ponds, fish breeding sites, landing sites Floods break down /damage the ponds and wash away the fish in them. Beside that they damage the fishing gears i.e., boats as well as nets hence affecting the fishing process. The Loss of fish and fishing gears brings poverty amongst the families that depended on fishing and aquaculture as they can no longer go fishing. On the other hand, damage to ponds and water bodies bring loss of fish and fish biodiversity to fisheries. The damage also brings loss of employment and therefore loss of income. Furthermore, unavailability of fish brings low intake of animal protein from fish and Omega fatty acids which is key to human health resulting into malnutrition.

Vulnerability factors

Deforestation as trees enhance infiltration of rain water, absence of tree means increased runoff and accumulation of waters in the low lysing or flat areas causing floods. Beside this Construction of ponds along the flood prone areas exposes the ponds to any slight flooding that may occur than if the crops were grown to upland areas away from the flood prone areas. Furthermore, having landing sites along the flood prone areas exposes the fishing gears and infrastructure to any slight type of flood that may occur and finally non availability of skills training in sea safety issues like swimming and putting on life jackets enhances the impact of floods on fisheries.

Exposure factors

The major exposure factors included the terrain of the land as most of floods occur in the floods occur in flat downstream areas. This is also where fertile land can be found. The poverty levels of the people enhance the impacts as people cannot construct good fish ponds or get better plots in the upland.

Adaptation measure

Afforestation process of introducing trees and tree seedlings to an area that has previously not been forested. Forestation, the act of restoring damaged forests where natural regeneration takes place by which juvenile plants and coppice that have established naturally replace plants which have died or have been killed; this is being caried out in Salima district. Beside this, the Government is training fish farmers to construct climate smart ponds which should have a minimum of 3m. What is often lacking is the knowledge to cope with and manage diseases when they appear, and the cascading impacts of extreme weather when fishponds are infiltrated by invasive species and pollutants.

Institutional capacity required

The following were mentioned - government to initiate provision of tree seedlings, communities to be trained in siting fish ponds and landing sites and enforcement of penalties on those that do not adhere to the rule and regulations of sea safety as capacities required to contain climate change effects.

d. Infrastructure damage

Participants noted that the previous floods damaged roads, bridges, buildings, electricity poles, power generation system as well as communication systems by causing damage to transmitters. They further damaged the sanitation systems leading disease outbreaks. These direct damages by the flood. The results of these direct effects are there is cut off to communication because bridges and roads are damaged. It disrupts the school calendar as school buildings collapse or are used as evacuation centers. Participants also noted that infrastructure damage leads to low economic productivity as communities have lost their business and are only kept at the camp and increases crime cases of theft as communities cannot find alternatives to fend for their living.

Commenté [J[103]: Please review language utilized here and provide sources for claims

Vulnerability factors

The following vulnerability factors were mentioned:

Deforestation: since trees enhance infiltration of rainwater, absence of tree means increased runoff and accumulation of waters in the low lysing or flat areas causing floods; Non flood resilient infrastructures, most of the infrastructure are weak to withstand the floods hence collapsing once floods occur. Furthermore, construction in the flood prone areas, coupled with low resilience, this increases the sensitivity to being destroyed by flood.

Exposure factors

The major exposure factors included Terrain of the land as most of the floods occur in the floods occur in the flat areas. Poverty levels of the people will enhance the impacts as people cannot construct good infrastructure or get better land in the upland.

Adaptation measures

Afforestation process of introducing trees and tree seedlings to an area that has previously not been forested, forestation, the restoring damaged forests where and Natural regeneration initiatives process by which juvenile plants and coppice that have established naturally replace plants which have died or have been killed is being caried out in Salima district.

Capacity required

The following were mentioned, government to initiate provision of tree seedlings, communities to be sensitized in dangers of constructing in flood prone areas. Relocation is another factor that was also mentioned where government is to identify land and resources for the displaced people.

e. Water and sanitation

Floods destroy sanitary structures such as sewage plants as well as latrines and also provide a conducive environment for waterborne diseases. These cause outbreaks of waterborne diseases such as Cholera, diarrhea and dysentery. Eventually, leading to disruption of economic growth of the country and families as government divert resources to hospitals to treat patients and secondly as sick people cannot participate in livelihood activities.

Vulnerability factors

Deforestation was considered to be the most impactful factor of vulnerability. by district respondents at the field mission workshop attached to this work. ~~to be~~ Trees cover up the ground and enhance infiltration of rain water, absence of trees means increased runoff and accumulation of waters in the low lysing or flat areas causing floods. Besides this, construction of shallow latrines in flood prone areas is another culprit since once floods occur the shallow latrines will collapse and all its contents (fecal matter) are released into the floods. Finally Improper disposal of wastes where refuse is just dumped anyhow. Once floods occur all the surface disposal waste find their way to waterbodies and cause various kinds of ailments.

Commenté [J[104]: word or words missing

Commenté [LF105R104]: Adjusted wording

Exposure factors

Terrain of the land as most of the floods occur~~-~~ in the flat areas. Secondly Poverty levels of the people will enhance the impacts. Biological factors such as sickness. Those that are sick have low immunity and easy to catch other diseases. In addition to this, age, the young and old can easily catch diseases that the youthful ones.

Adaptation measures

adaptation measures being carried out include afforestation, forestation and Natural tree regeneration initiatives, having waste disposal facilities and well designed and located latrines.

Capacity required

Government to initiate provision of tree seedlings, Recruitment of more offices to train communities.

b. **Drought and / or dry spells and extreme temperature**

There have cases of drought and dry spells in various places in Salima308. The dry spells are more prominent in the low-lying areas along the lakeshore where extreme temperatures are also experienced.[309]

a mis en forme : Exposant

Primary impacts of droughts

a. Crop production and livestock

It was mentioned that droughts cause crop damage as they cause the plants to wilt and at times completely dry up in hard ground that has been leached of moisture. This leads to low crop yields, culminating in hunger due to poor harvest, shortages of food and increased market prices. Outbreak of nutritional diseases occur due to poor harvests as communities do not have enough food; sickness and even death occur as people consume poisonous plants.

Vulnerability factors

Deforestation - absence of trees means increased runoff and accumulation of waters in low lying or flat areas causing floods. Use of non-drought tolerant varieties. This exposes the crops to death and wilting in every slight drought case that may occur. Poor agricultural practices which include farming without making ridges Making ridges along the slope so that water is channeled off the land. No contour bunds to control floods.

Exposure factors

Here we may refer to the terrain of the land as most of the floods occur in the flat areas such as the Shire basin floodplain and the coastal (lakeshore) strip.

Adaptation measures

Afforestation, forestation and tree regeneration initiatives, proper land use practices, smart agriculture and crop diversification are the initiatives mentioned required to prevent adverse effects of climate change.

Commenté [J[106]: This feels repetitive wit the section above on flood - please consider more concise ways to communicate this information

Capacity required

These included request for the government extension officers with training and knowledge who are ready to support and exchange knowledge and skills with local farmers and NGOs to initiate provision of seedlings, train communities in crop management and proper land use.

b. Fisheries and aquaculture

308 https://www.coopi.org/en/project/strengthening-resilience-of-vulnerable-communities-in-the-salima-and-mangochi-districts.html accessed on 28th October 2023

309 https://www.fao.org/family-farming/detail/en/c/422871/ accessed on 28th October 2023

Primary impact

The primary impacts of drought and extreme temperatures mentioned are drying up of fish ponds due to reduced water tables. These lead to secondary impacts such as mortality of fish or farmers are forced to harvest immature fish leading to disruption of business and associated fish value chains, loss of employment and increased poverty amongst the fish farmers.

Vulnerability factors

This includes deforestation because cutting down of trees exposes the soils to impacts of droughts and dry spells, constructions of ponds without a reliable source of water, Poor fish pond designs that are shallower and are not conducive to climate change impacts. Fishponds that do not have a waterproof base of clay or plastic – due to poverty.

Exposure factors

The major exposure factors include terrain of the land as most of the floods occur in the floods occur in the flat areas in addition to the geographical location.

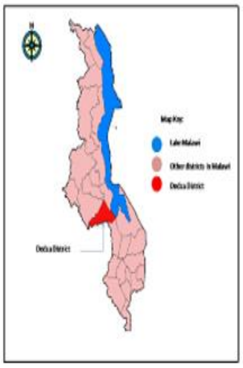
Adaptation measures

Afforestation, forestation and natural tree regeneration initiatives Construction of ponds in upper lands Training in climate smart ponds are what the participants mentioned as being dome to curb the impact of climate change on fisheries.

Capacity required

Members suggested to Government to initiate provision of training in how to carry out fish farming and seed money and equipment to get started. Communities to be trained in climate smart fishponds.

Annex 5: Dedza District - Climate Risk Assessment Report



Dedza District is located in the Central Region of Malawi with an estimated population of 830,512 people (2018), characterized by diverse geography, climate, and culture. It covers an area of approximately 3,624 square kilometres. The district is situated in the southern part of the Central Region of Malawi. It is bordered by Mozambique to the south, Lilongwe to the north, Ntcheu to the east, and Balaka to the west. The district has a somehow a temperate climate due to its elevation. The temperatures in Dedza vary with altitude but generally range from 15°C (59°F) to 27°C (81°F) and 37°C in October and November along the lake shore areas. The temperatures may go up to 8°C in June and July in the upland areas. The district experiences a wet season from November to April and a dry season from May to October. Annual rainfall averages around 1,000mm but can vary.

1. Social Economic Status

Agriculture is the backbone of the local economy. Small-scale farmers cultivate crops such as maize, tobacco, groundnuts, and vegetables. Livestock farming, including cattle and goats, is also a source of livelihood for many residents. Dedza Town, the district's capital, serves as a commercial and administrative hub, contributing to economic activities and trade.

2. Major Climatic Events

Dedza District, like other parts of Malawi, can experience climate-related challenges such as droughts, irregular rainfall patterns, and occasional dry spells, which impact agriculture and food security.

Climate variability, including the El Niño and La Niña phenomena, can affect weather patterns and conditions in the district.

3. Changing weather and climate patterns

Feedback from the FGDs confirmed that that there has been noticeable changes in climate and weather patterns in Dedza district. Heavy rains and strong winds, f~~F~~loods, extreme temperatures and drought / dry spells were mentioned as the major hazards experienced in Dedza district.

a. Heavy rains.

These have been common in Dedza over the years damaging both road and building infrastructure apart from causing Floods. In most cases the heavy rains are associated with strong winds: which add weight in causing horror to infrastructure in many areas. Schools, homes, and farms are particularly affected. Just like Salima the frequency of these strong winds termed "*mwela*" has impact on fishing and therefore affecting the fishing communities in the district by causing strong water currents and disturbing fishing.

b. Floods

This is another hazard devastating the district leading to huge loss of property, and life in some cases. The floods are common in low lying areas of the district especially along the shores of Lake Malawi in Mtakata and Golomoti.

c. Extreme temperatures and heatwaves

There have been cases of extreme heat and heat waves more pronounced compared to the past decades. This warming has brought cases of drying up of wetlands, crop damage and dying up of wells and surface water bodies dry up impacting winter cropping as well as fish farming in ponds.

Commenté [J[107]]: Can we base this analysis on a combination of the FGDs and the DCCCMS analysis?

d. Dry spells and drought

Dry spells lasting over three weeks are now frequent, severely damaging crops, drying up of fodder lands, leading hunger, loss of fish due to drying fish ponds, loss of fishing grounds and loss of animals. The unfortunate part of the dry spells is that they appear during the reproductive stages of the crops.

4. Climate risk assessment (CRA)– impacts and vulnerability analysis

Climate risk is the potential for climate change to create adverse consequences for human or ecological systems. This includes impacts on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services provision, ecosystems and species.

High risk is defined as a situation where the exposure to climate hazards is high the sensitivity of the system is high and the adaptive capacity is low.

Commenté [J[108]]: See note above on this sentence

On the other hand, Climate Risk Assessment (CRA), follows an impact assessment approach: hazard-driven and focuses on the impacts of climate change in a specific area or collection of assets. The assessment considers, for example, the risk of drought to food production in a set of regions.

A CRA for Dedza district was therefore conducted on Tuesday 26th July 2023 at the Mountain V~~v~~iew Hotel, near Dedza township. The following were the outcomes based on four climate Change Hazards, drought (dry spell), Extreme temperature, floods and Heavy rains and Strong winds.

a. Heavy rainfall and flooding

a. Impacts on crop production

Cases of heavy rainfall and strong winds are very rampant in Dedza. Almost every at least 2 to 3 areas are heavily affected causing massive destruction to various sectors of the economy. In January 2018, there were horrible heavy rainfall combined with hailstorm that caused extensive damage to crops in the district.[310]. This was subsequent to similar incidents in Mua area in TA Kachindamoto where in 2017.[311] heavy rains also destroyed hectares of crops. The heavy rains washed away crops and submerging of matured and small or immature crops, causing water logging in the fields and creating conducive environment for outbreak of pest and diseases and affecting plant growth by washing away fertile top soils.

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Consequently, these direct impacts of heavy rainfall on crops resulted into poor harvests as most of that culminated into food shortages, hence increased food prices leading to hunger and increased malnutrition and health problems. Since most of the families also depended on the crops as a source of income incidents of poverty and crime were rampant.[312] Coincidentally, other enterprises were also affected by the heavy rains and hailstorm hence impacting the livelihood alternatives of the affected communities and the district.

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[310] https://www.malawiproject.org/hailstorm-strikes-dedza/accessed on 14th October 2023
[311] https://www.maravipost.com/heavy-rains-cause-havoc-dedza/ accessed on 14th October 2023
[312] https://reliefweb.int/report/malawi/malawi-severe-weather-metmalawi-department-disaster-management-affairs-dodma-floodlist-echo-daily-flash-4-january-2023_ accessed on14th October 2023

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Vulnerability Factors

Deforestation emanating from opening of new farms (4%), charcoal burning (40%), brick curing, fuel firewood (32%), timber production (11%), tobacco curing and bush or forest fires,[313] has resulted in clearing of the forests leaving the land bare.[314]. This aggravated the situation especially when rain comes as there is usually heavy runoff and increased soil erosion.

On the other hand, poor land use and non-smart climate agriculture practices such as cultivating in river buffer zones, making ridges along the slope, not making box ridges, no storm drains and dykes and low crop diversification are another category of factors that increase the vulnerability of the communities to the heavy rains and storm drains. This is because there practices increases the velocity of the runoff hence causing more havoc.

Exposure Factor

Typically, Dedza is an elevated district which is Located at an elevation of 1580.67 meters (5185.93 feet) above sea level. It has a Tropical wet and dry or savanna climate. This climatic location compounded by the terrain of the area which is hilly in many area and low and flat along the lake sore increases the exposure of the district to incidents of heavy rains and floods.[315]. Besides this, poverty intensity in Malawi is very high (54% in rural areas),[316] and due to poverty, communities cannot manage the Smart Climate Agriculture system and cannot construct strong building that can resist heavy rains hence making them more exposed. Coincidentally, levels of poverty make communities resist to relocate because they can-not travel to distance places and cannot manage to build new homes when they relocate.

Adaptation Options

Issues of reafforestation where deforestation was done was mentioned as one of the activities that communities do. Afforestation where there has never been forest covers and tree regeneration are also conducted to bring back forest cover to buffer climate change effects. Re-afforestation is done in in individual farms, communal forests, and other protected areas. re-afforestation also includes promotion of fruit, trees, agroforestry trees, among others.[317]. During the FGD members noted that communities do crop diversification and as well as farming diversification to ensure that they still harvest when one crop is affected by fails. They also indicated the existence of variable source of income and use of alternative source of income so that communities do not rely on forests for their livelihoods as another adaptation strategy.

Capacity required

With the foregoing, the FGDs proposed the need for capacity building on the communities in managing natural resources by providing them with seedlings, training them in tree seedling management, empowering them with mind change concepts on dangers of wanton cutting down of tree. Members

[313] https://www.globalforestwatch.org/dashboards/country/MWI/6/?category=fires accessed on 13th October 2023
[314] Katummbi N, Nyengere J and Mkandawire E, 2015 Drivers of deforestation and Forest degradation in Dzalanyama Forests Researves in Malawi, International Journal of science and research.
[315] https://weatherandclimate.com/malawi/central-region/dedza accessed on 13th October 2023
[316] https://www.undp.org/sites/g/files/zskgke326/files/2023-08/Malawi-Multidimensional%20Poverty%20Index%20Report_0.pdf accessed on 13th October 2023
[317] http://www.aejmalawi.org/news/?village-chief-leads-re-afforestation-efforts-in-dedza-a398c9baa0fd87189b9cc 04e1d735c74 accessed on 13th October 2023

also proposed increasing the number of extension workers in the district so for effective and improved training on Forestry issues.

b. Livestock production

Dedza has been hit by various Climate Change disasters among which was Cyclone Idai in 2019. Among the primary damages on livestock was loss of livestock by being drowned or washed away by the heavy rains, damaging of livestock kraals and loss of pastures. These livestock include cattle, goats, sheep as well as chickens. More than 47,000 livestock were washed in cyclone Idai disaster.[318] Dedza was not exceptional. Damage to livestock kraals and loss of pasture. The recent 2023 cyclone Freddy affected more that 280,000 livestock.[319] The repercussion of these losses is loss of income as livestock is considered as an investment to the communities. As such, cases of poverty amongst the communities, scarcity of meat and meets products are common. These impacts culminate into school drop outs as families will not have of income to pay schools fees for their wards. Families that have lost livestock are likely to face hunger as livestock are also a food security commodity. With the increased poverty levels, cases of theft and rise in other crimes is high.

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<u>Vulnerability Factors</u>

A number of factors were mentioned during the participatory discussion as vulnerability factors, these include: Non climate smart animal houses, grazing and keeping animals in flood prone areas as well as Deforestation that enhances runoff from the upland Grazing. Usually, rains come by surprise and at times at time when the people are in total darkness. As such it is difficult to rescue animals at the cost of saving human life.

<u>Exposure Factor</u>

The Terrain of Dedza especially which is flat and low lying at the lake shore, the hilly part that discharges heavy rainfall during runoff, are some of the exposure factors to climate change impacts.

<u>Adaptation Options</u>

Afforestation especially at individual farms, communal forests, and other protected areas has been one of the adaption measures that is being conducted in Dedza in order to reduce impacts of climate change. The afforestation is done using fruit, trees, agroforestry trees, as well exotic and indigenous trees. Apart from this, farmers are taught to construct animal houses that are resilient to climate change effects. Furthermore, communities are advancing the idea of having alternative Income generating activities that will ensure the continued support from other sectors when livestock has failed to support their livelihoods.

<u>Capacity required</u>

The participants mentioned the need the recruitment of extension workers that are in deficiency in Dedza as one way of promoting capacity in fighting climate change. The extension workers will be responsible for providing training and guidance on implementation of various adaptation measure being implemented in the district. On the other hand, individual mentioned the subsiding of tree

[318] https://www.unicef.org/malawi/media/1756/file/ Malawi%202019%20Floods%20Post%20Disaster%20 Needs%20Assessment%20Report.pdf accessed on 14th October 2024

[319] https://www.unicef.org/malawi/media/1756/file/Malawi%202023%20Floods%20Post%20Disaster%20 Needs%20Assessment%20Report.pdf

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seedlings as well as alternative sources of energy to ensure there is enough soil cover but also reducing deforestation for fuel wood.

c. Fisheries and Aquaculture

Fisheries and aquaculture were mentioned as one of the sectors that has been b heavily affected by climate change in Dedza. The Fisheries aspect was mentioned as the eastern part of Dedza boarders Lake Malawi where fishing is also conducted. The Aquaculture part was also mentioned as considering fish ponds that have been heavily affected by floods over the years.

Primary and secondary impacts

The heavy rains resulted in floods that washed that destroyed the fish ponds and washed away the fish. Apart from that the floods destroyed that breeding sites of fish especially along the lake by causing siltation there by affecting the biodiversity and fish catches. Washing away fish ponds. The floods also led to loss of the landing sides as the sites were taken away by the floods leading to loss of property that included infrastructure and household items. This eventually affected family income and food security of the families. The reduced catches led to low fish and therefore animal protein consumption affecting the nutrition of the people, Increased poverty amongst the communities as fishing was a source of employment. ~~The p~~Poverty also increased~~creeped~~ because~~ the~~ ponds were ~~also ~~washed away by the floods making the farmers lose all their investments in aquaculture. Furthermore, the floods led to loss of fishing gears such as nets and boats causing loss of family investments.

Commenté [J[110]: Unclear

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Vulnerability Factors

It was noted that poor siting of fish ponds where the ponds are constructed in the flood prone areas is one of the causes of pond destruction and washing away of fish during floods and heavy rains. Besides, the ponds are mostly poorly constructed with weak walls as well as shallow depth that would increase their proneness to climate change effects. Besides landing sites for fishermen are too close to the lake shore where they have their make shift homes and have their property right there. Once floods occur all property is washed away. Furthermore clearing of buffer zones for the lakes and river for hotel building as well as farming enhances rise in water and flooding.

Exposure Factor

The terrain of Dedza district which is hilly and low-lying areas makes the runoff be high and but also at the same time all the water accumulates at the flat area. This enhances the sensitivity to heavy rains and floods impacts on the fish ponds and also landing sites as they become flooded and the fish breeding sites silted by soils eroded from the uplands where non smart agriculture is being practiced.

Adaptation Options

A number of options were proposed as adaptation measures being done and these included, proper site selection for pond construction, construction of climate smart ponds which will be resilient to floods and heavy rains. Besides this communities are constructing contour bands and planting vetiver grass in places that are prone to erosion. Furthermore, farmers are advised not to cultivate close to the river banks and at least leave a buffer strip along the rivers and lakes

Capacity required

Recruitment of extension workers to train the fish farmers, diversification in IGA by providing them capacity support in loans and training will reduce the sensitivity of the heavy rainfall and floods hazards on the communities.

d. Infrastructure/Water

Infrastructure includes buildings, roads, bridges, hospitals, dams, utility infrastructure and many others. These are also affected in various ways by the presence floods and heavy rainfalls

Primary impacts on infrastructure

Issues such as damage to roads, bridges, schools, hospitals and houses were mentioned as some of the effects of heavy rains and floods on infrastructure. In 2003 5637 house were damaged~~[320]~~ in Dedza alone and many more bridges and roads.[321] This resulted in displacement of families, contamination of waters disruption of communication, loss of human life, reduced access to market and social services disruption of families, increased pregnancies, disease outbreaks such as choler which killed about 1,400 people and affected more than 45,400 people[322]. Furthermore, damage to infrastructure disrupted school calendars thereby increasing school dropouts, brought unplanned teenage pregnancies and loss of moral values, Increased theft, children cut off from education facilities because schools were used as evacuation centres, disruption of businesses and reduced economic productivity and congestion in the hospitals.

Vulnerability factors

A number of factors were mentioned that enhance the impacts of floods on infrastructure damage. These included, deforestation, poor housing designs, weak infrastructure that is not resilient to floods, unavailability of evacuation centres hence schools and churches being used and dishonest apprentices

Exposure Factor

The terrain of Dedza district which is hilly and low-lying areas makes the runoff be high. Poverty, sickness and age and gender are additional exposure factors.

Adaptation Options

The communities mentioned that so far, they are conducting afforestation, increased use of alternative energy sources, reduce use of unskilled apprentices and fight corruption, Putting up evacuation centers and relocation of people to upland areas as some of the adaptation measures.

Capacity required

There is need for authorities to provide Land and resources for construction of evacuation centers, relation of affected individuals, train more engineers and subsidise building materials.

b. Drought/prolonged dry spell

Drought is a prolonged dry period in the natural climate cycle that can occur anywhere in the world. It is a slow onset phenomenon arising from inadequate rainfall or snowfall, resulting in water scarcity, parched soil, and crop harm. The beginning and end of **droughts** are uncertain. The impacts of drought are usually classified based on the area of sector.

~~320 https://reliefweb.int/report/malawi/malawi-floods-ocha-situation-report-no-1-0 accessed on 23rd October 2023~~

321 https://reliefweb.int/report/malawi/malawi-floods-ocha-situation-report-no-1-0 accessed on 23rd October 2023

322 https://www.unocha.org/publications/report/malawi/malawi-cholera-floods-flash-appeal-2023-revised-march-following-cyclone-freddy-february-june-2023, accessed on 23rd October 2023

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a. Impacts on crop production

Droughts cause crop damage by causing wilting and drying of crops due to no rains and drying up of ground water that provide moisture for the plants. Participants noted also Increased incidence of pests and diseases including Fall Army Worm which mostly are common during drought and prolonged dry spells.

The results of crop damage due to drought are Low crop yields that leads to shortage of food comminating into High prices of food crops on the market, increase in hunger, -Increase in malnutritional diseases due to lack of variety of food groups, loss of income and loss of lives. Subsequently there is reduced economic activities, low family incomes and shortage of waters and increased poverty levels and increased school drop outs and increased crime rates.

Vulnerability factors

Issues of deforestation, overgrazing, non-climate smart agriculture, Poor extension services low crop diversification, low income households , limited accessible agricultural information negligence in maintaining best practices, using crop varieties that are not drought tolerant were raised as some of the factors enhancing the effects of drought.

Exposure factors

Geographical location and terrain are the two major exposure factors affecting the extent of the impact of this climate hazard. Poverty, age and gender are some of the exposure factors mentioned.

Adaptation measures

Use of early maturing varieties, proper land use practices, Afforestation, Reforestation and tree-regeneration to bring back the forest, Use drought tolerant crops, crop diversification, Irrigation awareness campaigns about the roles of tress and forests, Promoting climate smart agriculture are some of the activities being conducted by the communities as adaptation measures to climate change hazards

Capacity requirements

Members suggested development of Human capacity, Financial resource, Early warning information system, tree planting projects. Beside there should be initiatives to provide necessary resources, especially tree seeds, for reforestation and ensuring availability of tree seedlings among community members.

b. Fisheries and aquaculture

Drought has cause loss /death of fish both in natural and aquaculture facilities. This is because there has been drying up of shallow water bodies as well as fish ponds leading to loss of fishing grounds, increase diseases occurrence, loss of breeding sites loss of business. This has resulted in reduced fish yields and catches affecting families income leading to low protein intake, loss of employment increased crime rate and disturbed families as fishers trek to other fishing grounds.

Vulnerability causes

Deforestation, destroying of wetlands, destruction of breeding sites, non-climate smart ponds Poor sting of ponds, are some of the factors that enhance the impact of drought on fish and fisheries.

Exposure factors

Geographical location and terrain are the two major exposure factors affecting the extent of the impact of this climate hazard. Poverty, age and gender are some of the exposure factors mentioned.

<u>Adaptation measures</u>

Good Site selection- Use guidelines provided in identification of sites for pond. Protecting the wetlands, construction of climate smart fish ponds and adjusting to cage fish farming are some of the adaptation measures being done.

c. **Extreme Heat/Coldness**

Similar to the other hazards, the impacts of extreme heat area as follow:

a. **On Crops production**

The extreme heat damage crops either through wilting or total drying up if the heat has been there for extended period of time. The repercussion of drying crops is low yields leading to increased food prices, hunger, poverty, malnutrition in extreme cases there could be loss of huma life as well as livestock. the extreme heat also render reduction in productivity as individuals work only during morning. Further extreme heat cause drying up of water bodies and pasture for animal grazing.

<u>Vulnerability factors</u>

Poor agricultural practices, deforestation, poorly designed houses, non-drought tolerant crops as well as no crop diversification are the major factors that enhance repercussions of heatwaves and coldness in Dedza district.

<u>Exposure</u>

The heat waves are mostly common in the low-lying areas along the lake shore. As such, Terrain and Geographical location of an area are the major exposure factors for hit waves. However, Poverty, age as well as sickness are other exposure factors that enhance the impact of heat waves on crops and livestock as well as human beings.

<u>Adaptation measures</u>

Currently individuals are encouraged to always do crop diversification so that they can depend on one crop when another fails, use drought tolerant crops, early maturing crops and well as afforestation.

<u>Capacity required</u>

Availability of finances, subsidised tree seedlings, extension workers were, drought tolerant crops as we well as human resources are the main materials resources that participants mentioned as part of required capacity to ensure adaptation measures are.

Annex 6: Rumphi District – Climate Risk Assessment Report

1. Introduction

Rumphi district is in the Northern Region of Malawi. The district covers an area of 4,769 sq km and has a population of 128,360. Rumphi district extends from Lake Malawi in the east to the Zambian border in the west. In Rumphi, the wet season is humid and overcast, the dry season is windy and mostly clear, and it is warm year-round. Over the course of the year, the temperature typically varies from 54°F to 87°F and is rarely below 50°F or above 91°F.The hot season lasts for 2.2 months, from September 30 to December 4, with an average daily high temperature above 83°F. The hottest month of the year in Rumphi is November, with an average high of 86°F and low of 67°F.

The cool season lasts for 2.8 months, from May 15 to August 7, with an average daily high temperature below 73°F. The coldest month of the year in Rumphi is July, with an average low of 54°F and high of 71°F. In Rumphi, the average percentage of the sky covered by clouds experiences extreme seasonal variation over the course of the year. The clearer part of the year in Rumphi begins around April 8 and lasts for 7.3 months, ending around November 17. The clearest month of the year in Rumphi is July, during which on average the sky is clear, mostly clear, or partly cloudy 86% of the time. The cloudier part of the year begins around November 17 and lasts for 4.7 months, ending around April 8.

The northern end of the Mzimba Plain extends into the eastern portion of the district. Most of the district is drained by the South Rukuru River and its tributaries. The Viphya Mountains extend into the southeastern portion of the district, and much of central portion of the district lies on the Nyika Platea. Vwaza Marsh Wildlife Reserve covers the western end of the district, and Nyika National Park covers much of the centre.

Rumphi district is blessed with several perennial rivers which gives it a great potential for irrigated agriculture. The district has capacity to do rain-fed and irrigated agriculture and diverse types of crops are grown and animals kept for both consumption and income generation (GoM, 2005).

Even though maize and tobacco are the main crops in the district, farmers cultivate a wide range of crops both for consumption and sale. These, among others, include cassava, beans, groundnuts, sweet potatoes, rice, millet, pulses, European potatoes and paprika. A wide range of horticultural crops and vegetables are also cultivated. These included bananas, mangoes, oranges, tangerines, macademia, coffee, guavas, pawpaws, coffee, onions, and tomatoes.

Crop yields are well behind the average potential mainly due to limited use of improved seed varieties, low utilization of fertilizer, low utilization of manure, poor pest, and disease management practices. In some areas such as Bolero, Mhuju and Lakeshore areas, agricultural productivity is constrained by erratic rains and poor soil fertility.

Some few areas such as Mwachenga, Mwalweni and Mwankhunkwa rain-fed agriculture is supplemented by irrigation particularly gravity-fed irrigation, treadle and motorized pumps or residue moisture to either grow a second or third crop.

Business activities are essentially vibrant in Rumphi, but entrepreneurs are limited to realize their full potential due to capital constraints. Access to finance capital is limited due to restrictive lending practices for those who do not have meaningful collateral in the form of assets or financial deposit.

Rumphi has an extensive road net work but most of it becomes inaccessible for most part during the rainy season. Most of the roads in Rumphi are earth with gravel or non-gravel except for 3 roads including M1 which are bitumised. These roads are generally passable during the dry season but pose some serious mobility challenges during the rainy season.

2. Climate Hazards

Rumphi district experiences various climatic hazards but the most common ones are extreme heat, drought/dry spell storm- strong winds and heavy rains, and flood.

a. Extreme Heat

For Rumphi district extreme heat hazard is classified as low based on modelled heat information currently available at Think Hazard tool.[323] There is between a 5% and 25% chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years.

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The temperature increase in the next fifty years will be slightly lower than the worldwide average, but still significant. It would be prudent to design projects in this area to be robust to global warming in the long-term.

b. Storm (Strong winds and heavy rains)

Rumphi district has frequent occurrence of rainstorms for example in 2017 the district experienced heavy rains and strong winds. In 2019 Rumphi district experienced another storm disaster.

c. Drought/ Dry spells

Drought is a gradually evolving hazard leading to water scarcity that impact large geographical areas and multiple sectors, ranging from drying up of water bodies- river, wells.

Water scarcity is classified as low according to the information that is currently available. There is a 1% chance that drought will occur in the coming 10 years. the impact of drought should be considered in all phases of the project, in particular its effect on personnel and stakeholders, and during design of buildings and infrastructure.

Geographical location of Rumphi district especially Bolero area makes it a shadow area where rain is always erratic.

d. Floods

River flood hazard is classified as low based on modelled flood information currently available to the Think Hazard tool.[324] This means that there is a chance of more than 1% that potentially damaging

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[323] https://thinkhazard.org/en/report/19320-malawi-northern-region-rumphi/EH

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[324] https://thinkhazard.org/en/report/19320-malawi-northern-region-rumphi/FL

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and life-threatening river floods occur in the coming 10 years (return period of c. 1 in 1000 years). Flood hazard can vary dramatically over short distances, depending on factors such as local topography and distance to waterways.

Flooding is most likely to occur in relatively flat areas beside rivers ('floodplains'), in local low points in the land surface ('depressions'), or along valley bottoms. If the project is situated on the top or side of a hill then it is unlikely to be directly at risk from river flooding. A project situated at the base of a hill or on flatter terrain put people at a position of being more likely to be at risk. Flood risk may not always originate from the closest point on the river. One may also be at risk from flood waters that overflow from the channel upstream before flowing downhill over the floodplain. For Rumphi district this situation is a common practice due to the topography of the area. Flash-flooding is also a common occurrence from small streams which pose a great risk.

3. Sectoral Impacts and future risks

a. Impact on Agriculture- Crop production, livestock production

a. Crop production

Crop yield may be adversely affected by heat, especially if the heat is accompanied by drought.

Drying of crops lead to low yields which eventually lead to low supply of food. This led to increased prices making food unaffordable to many people especially poor, marginalized groups (disabled, elderly, women, youth).

Increased disease and pests outbreak due to wilting of grasses which makes pests attack crops because of disruption of their habitats.

Destruction of crops through uprooting and breaking stems. The storms cause landslide which damages property and buildings (schools, houses). The fast-moving water from the storms damage roads and bridges. The surface run off water strong winds destroys crops and uproots plants and break crop stems.

Wilting and drying of crops. Crop failures and reductions in food production to reduced availability of electricity and fresh water.

Floods washed and destroyed crops in the fields due to excess water, resulted into water logging of fields reducing crop yields. Low yields resulted into low food production which affected food security and livelihoods of affected people in particular marginalised groups (elderly, women, disabled and children).

Crop damaged results into low yields culminating to food insecurity and high prices of food crops. Shortage of food crops increases hunger and malnutrition problems for affected people and more specifically marginalised groups.

b. Livestock production

Livestock production may become compromised during periods of extreme heat, especially intensive dairy cattle systems, owing to decreased fertility and increased mortality, reduced milk production and associated income losses. Poultry and pigs are also sensitive to extreme heat.

Damage livestock kraals. Floods washed and destroyed crops and killed livestock. Flooding of rivers washed and killed livestock resulting into loss of income for the farmers.

Vulnerable groups, especially children, disabled, women and elderly face increased food insecurity and malnutrition due to damage of crops and livestock.

Drying of crops lead to low yields which eventually lead to low supply of food. This led to increased prices making food unaffordable to many people especially poor, marginalized groups (disabled, elderly, women, youth).

b. Impact on forestry

Under conditions of combined heat and drought, there is an enhanced risk of forest fires, heat-induced tree mortality and decline in tree growth rates, impacting forestry projects. Dedicated species-specific growth curves, which express plant growth response as a function of temperature, can be used to estimate impact on forestry projects.

c. Impact on Fisheries

Mudslide, and high soil erosion and high siltation of fish breeding sites.

Drying up of fishponds affects fish production from ponds through increased predation, mortality of fish. Reduced fish production.

d. Impact on infrastructure, water, electricity

Rainstorms destroyed schools and some houses in Rumphi district. Reports showed that rainstorm in 2017 Phwezi secondary school and Phwezi Technical College were damaged due to the strong winds which came with heavy rains. Headteacher for the secondary school Thomas Kaumba confirmed that two schoolteachers' houses, one hostel and the institution's administration block were damaged. The heavy rains also damaged the institution's water taps as well as electricity.

The disaster resulted in the death of three people in a landslide and injured nine people and five people went missing. The disaster affected a total of 20 households (about 100 people), and damaged personal and public infrastructure such as houses and schools.

Energy production, especially electrical energy production, is particularly vulnerable, given that the infrastructure for production and transmission (e.g., transformers) of electrical energy may experience breakdowns in periods of extreme heat. Moreover, periods of extreme heat often go together with an increased electricity demand peak for active building cooling, and at the same time coincide with an increased difficulty in obtaining sufficient cooling water for thermal power generation during very hot conditions.

Renewable energy production, solar based (photovoltaic (PV) panels and concentrating solar power (CSP) plants) may see their output reduced in periods of high temperature. In the case of PV modules, one should account for the temperature dependent electrical efficiency, and implement mitigating measures, such as installing PV panels a few inches above roofs to allow convective air flow to cool the panels.

Industrial plants may have difficulties cooling, especially those that depend on natural cooling from wind. In addition, heat-induced energy production may decrease and negatively affect the operations at industrial plants.

Transport infrastructure is also sensitive to extreme heat. Road pavements may get damaged, and car tires may experience failure at high temperatures.

Contamination of water sources.

Damaged roads and bridges disrupted transportation and access to basic amenities, markets, and health services. The situation resulted in scarcity of commodities and increased prices making it difficult for marginalised groups (women, children, elderly and disabled to access them)

Floods damaged infrastructure, property, and buildings (roads, schools, toilets, and bridges) which disrupted access to social services, education health services, markets, food, water, and shelter.

Damage of water and sanitation facilities (boreholes, shallow wells, and toilets) resulted into contamination or forces people to use unprotected water sources which results into increased incidence of waterborne diseases particularly diarrhoea and cholera. Stagnant water provided favourable environment for mosquito breeding and increased spread of malaria impacting the health people.

Damaged school blocks results into disruption of learning and sometimes contributes to drop out of school children especially girls when toilets get destroyed. Floods damaged infrastructure (roads, schools, toilets, and bridges) disrupting transportation and access to school for learners.

Destruction of houses resulted into homelessness and internal displacement and migration for vulnerable households especially child-headed households.

In some cases, heavy rains and strong winds resulted into loss of lives. The strong winds affected boats on the lake where 11 people went missing in 2020 because the boats capsized. Children of missing people became orphans.

Stagnant water after floods provided a conducive environment for breeding of mosquitoes which spreads malaria and spread of other water borne diseases. This affected the health of people especially vulnerable groups.

Floods cause disruption of transport due to damaged roads thereby distorting the food supply.

Poor water drainage system which accelerates run off and flooding of water.

e. Future risk for the district

To further determine the potential risk, a detailed assessment should be undertaken to identify the vulnerability of any project to be carried out in Rumphi district. The assessment will determine the extent of water scarcity condition. To further determine the potential risk caused by drought a detailed assessment is needed to determine the vulnerability of project beneficiaries to water scarcity and drought related problems such as food security and failing crops, or the potential disturbance of public services (transport, communication, sanitation fresh water, and electricity supply) and its impacts on the project.

The potential flood risk can be defined through undertaking, a local assessment to identify whether any sources of flooding exist (rivers/streams). Location assessment is done to gain a greater understanding of the likely flood hazard at defined location, through the interpretation of the local landscape.

The position of the project in the landscape should be considered by assessing local topography (i.e., how flat or steep the area is).

The major risks include death of people, injuries to people who get washed away through destruction of houses, loss of property during climate hazards and damage to infrastructure, loss of people's homes due to climatic hazards and loss of livelihoods.

Settling and farming in disaster prone areas at the foot of steep slopes in Chiweta Hills in Rumphi districts results in increased exposure to climate hazards.

There is challenging topography in certain areas in Rumphi where there are very steep slopes that are prone to land and mudslide.

Poor agricultural practices and growing crops along riverbanks enhances exposure to impacts of heavy rains. Bad agricultural practices of cultivating along steep slopes have worsened the situation by exposing the soil and accelerating water run-off.

Construction houses in flood prone areas and constructing substandard houses using poor construction materials (unburnt houses) increases the chances of severe damage by climate hazards.

Weak infrastructure- school buildings, heath facilities, roads, bridges, water facilities are more vulnerable to climate hazards- heavy rains and strong winds, floods.

Marginalised people (elderly, disabled, women and children) who are poor and with low income are more vulnerable to effects of storms.

Weak institutional capacity coupled with corrupt practices to enforce bylaws for land use planning, construction standards greatly compromise the quality of infrastructure.

Deforestation due to cutting down trees to open new agriculture land, for fuel wood, charcoal and income have exposed the land to run off and soil erosion.

Annex 7: Karonga District - Climate Risk Assessment Report

1. Introduction

Karonga district is in the Northern Region of Malawi. The district has an area of 3,355 km² and a population of 365,028. The district is on the border between Malawi and Tanzania, mainly occupied by the Nkhonde and Tumbuka tribes. Other tribes include Henga tribe (mainly occupying the southern part).

There has been much development in Karonga district over the last years due to the discovery of uranium at the Kayelekera mine which officially opened in 2009 and many of the previously gravelled roads were upgraded to tarmac. Most of the infrastructure were upgraded including water facilities.

The district has many hotels and guesthouses along the shore of Lake Malawi. The Karonga Museum at Karonga Centre attracts more visitors. More people pass through the district on transit doing cross border trade from Tanzania which enhances economic activities.

The district is also popular for production of Kilombero rice which has favourable aromatic characteristics.

Karonga district experiences a sub-tropical climate which is relatively dry. The season for rain starts from November/December to April the following year, and the dry season from June to October. The temperatures are warmest during October and November (the period just before the rainy season starts). It remains hot throughout the wet season and gets a little cooler during the dry season. The temperatures are lowest from June to August.

Karonga district experience various climatic hazards but the most common ones are extreme heat, drought/dry spell, and flood. The climate hazards have various impact on the socio-economic fabric of the population in Karonga district. The main concern is the increased frequency of the occurrence of these hazards and the scale of impact.

2. Climate Hazard

Karonga district experiences various climatic hazards with extreme heat, drought/dry spells, floods, and storm (strong wind and heavy rains) being the most common. As has been noted earlier, Karonga District's climate is influenced by different factors to the rest of the country so that Karonga may be experiencing drought while the southern Region is overwhelmed by storms and flooding as happened during the rainy season 2022/23.

a. Heat wave or extreme heat

Extreme heat is classified as a medium hazard for Karonga District based on modelled heat information currently available on the Think Hazard Tool.[325] This means that there is more than a 25% chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years. The district has a fairly week seasonal variation in temperature. The difference between

[325] https://thinkhazard.org/en/report/19317-malawi-northern-region-karonga/EH

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the temperatures during the hottest and coldest time of the year is relatively small, around 6° C. The diurnal cycle (i.e., the difference between highest temperature during the day and the lowest temperature at night) may be more noticeable than the seasonal cycle. The average difference between the hottest and the coldest temperature within a day is just over 9° C. From year to year, temperatures do not vary much in terms of the average monthly or seasonal temperature. The variability of extreme temperature events through time has been high in Karonga.[326]

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The frequency of extreme heat events (very hot days and nights) has also gone up over time. The number of very hot days has gone up by more than 3 days every ten years, while the number of very hot nights has gone up by more than 9 days every ten years. The season in which very hot nights happen has also gotten longer over time. Historically, very hot nights happened mostly in November, but now they can happen from October through to February (of the following year).

Extreme heat is a hazard that typically evolves over periods of days to weeks, affecting large geographical areas (extending over thousands of kilometers) and impacting multiple sectors, including human health, energy consumption and production, industrial plants operations, transportation infrastructure, livestock production, crop yield, forestry, tourism, and labor productivity. Heat waves can compromise public health, reduce productivity, and constrain the functionality of infrastructure.

Extreme heat has impact on human health. Extreme heat constitutes the single most deadly meteorological calamity, also because extreme heat events often coincide with high levels of atmospheric pollution. Urban populations and those working outdoors in urban or rural areas are most vulnerable.

Extreme heat hazard often occurs together with drought (water scarcity). Heat and drought combined may reinforce each other's impacts, e.g., during an extreme heat episode, an industrial plant may require enhanced cooling, but a concurring drought might limit the availability of cooling water.

b. Drought/dry spells

Drought is classified as low according to the information that is currently available. This means that there is a 1% chance that drought will occur in the coming 10 years. The impact of drought should be considered in all phases of development projects, in particular its effect on personnel and stakeholders, and during design of buildings and infrastructure.

c. Floods

Flood hazard is classified as medium based on modelled flood information. This means there is a chance of more than 20% that potentially damaging and life-threatening floods occur in the coming 10 years according to the Think Hazard Tool.[327] The present hazard level may increase in the future because of climate change. It would be prudent to design projects in this area to be robust to river flood hazard in the long-term.

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3. Sectoral Impacts and future risks

a. Impact on Agriculture- Crop production, livestock production

326 https://assets.publishing.service.gov.uk/media/5a041a30e5274a0ee5a1f15c/Karonga_climate_profile_summary_version_final_2_.pdf

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327 https://thinkhazard.org/en/report/19317-malawi-northern-region-karonga/UF

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a. Crop production

Crop yields are adversely affected by extreme heat, especially if the heat is accompanied by drought. Extreme heat resulted into withering and drying of crops, rotting of fresh food markets (e.g., tomatoes and fish), decreased water levels, and drying of water infrastructure.

The prolonged absence of rainfall resulted in significant crop loss, which affected maize and rice production. Farmers experienced reduced yields and even total crop failure of rice, maize, and pigeon pea crops in some fields. The climate hazards results into low availability and quality of crops such as tomatoes.

Decreased rice productivity in Karonga and a complete absence of maize in the southern part of the district resulted in importation of maize from Tanzania. The low crop yields resulted in food shortages and increased poverty levels within the community.

Scarcity of food crops has driven up prices, making it difficult for the community to afford basic food necessities.

Floods damaged agricultural fields, resulting in the loss of vital food and income sources for households.

The destruction of crops contributed to food and nutrition insecurity within the community. The loss of food sources and limited access to markets aggravated the challenges faced by households.

Floods washed away and covered farmlands with sand dunes, rendering them unsuitable for cultivation.

The loss of arable land reduced agricultural productivity and exacerbates food insecurity in the district.

Drought and dry-spell events decreased agricultural output and loss of livelihoods for farmers, leading to a significant loss of income within the community.

In some cases, flood events resulted in fatalities and causing loss of life in some communities especially along South Rukuru River.

Floods damaged roads and transportation infrastructure, disrupting transportation and access to essential services. School blocks and other infrastructure were also affected, disrupting education and community services.

b. Livestock production

Livestock production become compromised during periods of extreme heat, especially intensive dairy cattle systems, owing to decreased fertility and increased mortality, reduced milk production and associated income losses. Poultry and pigs are also sensitive to extreme heat. Drying of pastureland reduced livestock productivity due to stress caused by insufficient feed and dehydration. Drought and dry-spell events caused loss of grazing land, leading to inadequate food and water resources for livestock. Drying of pastureland resulted into reduced grazing areas for livestock which forced people to sell some of the animals at noncompetitive prices.

Heatwaves accelerated the spread of livestock pests and diseases such as fleas, ticks, and New castle East Coast fever, further impacting livestock health. Birds have been adversely affected by the lack of sufficient shade due to extreme heat events. Livestock deaths resulted in food shortages and increased poverty levels within the community.

Floods damaged livestock kraals, resulting in the loss of vital food and income sources for households. Flood also damaged grazing areas reducing pasture for cattle, goats, and sheep thereby reducing livestock productivity. Flood water washed away some livestock. Flood water washed away crops and some livestock. Flood also washed livestock which resulted to death of livestock in particular chickens, pigs, and cattle.

The loss of income and food due to drought and dry-spell events pushed some women in a very awkward situation. To meet their basic needs, some women engage in prostitution, leading to sexual exploitation and associated risks.

The limited availability of food resources and loss of agricultural productivity have contributed to an increase in malnutrition cases, particularly among vulnerable groups such as children and pregnant women.

The loss of crops, livestock, and income sources due to floods intensifies poverty and hunger within the community. Household livelihoods were severely affected, leading to increased vulnerability to food insecurity and economic hardship.

b. Impact on forestry

Under conditions of combined heat and drought, there is an enhanced risk of forest fires, heat-induced tree mortality and decline in tree growth rates, impacting forestry projects. Dedicated species-specific growth curves, which express plant growth response as a function of temperature, can be used to estimate impact on forestry projects.

c. Impact on Fisheries

The decrease in water availability and drying of water bodies has directly affected aquatic life, causing a decline in the number of fish. This has negatively impacted the fishing industry resulting into low availability of fish resulting into low consumption of fish protein and food insecurity.

d. Impact on infrastructure, water, electricity

Drought and dry-spell and extreme heat events led to the drying up and reduction of water bodies, causing drying severe water scarcity in the district. As a result, domestic water sources, such as boreholes, dried up, exacerbating the water crisis.

The reduction and contamination of water sources due to drought have resulted in health issues within the community. Access to safe and clean water becomes limited, increasing the risk of waterborne diseases and other health complications.

Water bodies in Karonga experienced a decrease in water levels, affecting domestic water supply.

Flood events led to the displacement and loss of homes for many individuals and families in Karonga District. The destruction of houses and infrastructure left people homeless and without access to safe drinking water.

Energy production, especially electrical energy production, is particularly vulnerable, given that the infrastructure for production and transmission (e.g., transformers) of electrical energy may experience breakdowns in periods of extreme heat. Moreover, periods of extreme heat often go together with an increased electricity demand peak for active building cooling, and at the same time coincide with an increased difficulty in obtaining sufficient cooling water for thermal power generation during very hot conditions.

Renewable energy production, solar based (photovoltaic (PV) panels and concentrating solar power (CSP) plants) may see their output reduced in periods of high temperature. In the case of PV modules, one should account for the temperature dependent electrical efficiency, and implement mitigating measures, such as installing PV panels a few inches above roofs to allow convective air flow to cool the panels.

Transport infrastructure is also sensitive to extreme heat. Road pavements may get damaged, and car tires may experience failure at high temperatures.

Labor productivity is also impacted by extreme heat, especially in the case of outdoor workers, or workers in poorly cooled or ventilated buildings. agricultural, manufacturing, and construction workers are among the most vulnerable groups to outdoor heat.

There is also socio-economic impact of climate hazards. For example, extreme heat hindered the functioning of fresh food markets, affecting the availability and quality of crops such as tomatoes and fish. There is also loss of income sources due to extreme heat events through disruption of services due to destruction of roads and transport of people. making it challenging for families to meet their basic needs. The population staying at home during heatwaves led to the closure of businesses, causing financial losses for entrepreneurs.

The loss of food sources and income has resulted in food and nutrition insecurity, increasing the risk of malnutrition within the community.

Women and youth in Karonga have experienced property loss due to loans and predatory lending practices.

Hunger and food scarcity may lead to family members seeking food elsewhere, potentially resulting in family separation and social disruption.

e. Summary impacts

Desperation arising from the lack of resources, income, and food during flood events led some individuals, particularly young men, to engage in theft and robbery activities. The displacement of people during evacuations provided an opportunity for looting.

Floods destroyed education facilities and constrained affected communities which contributed to increased school dropouts and lower literacy levels within the community.

Floods disrupted transportation and blocked markets due to flooded areas resulted in a loss of income for businesses and traders. For instance, Ngara Trading, a significant market, became inaccessible due to water, affecting the local economy and livelihoods of people.

Extreme heat events have led to increased cases of high blood pressure, causing people to lose consciousness. Additionally, individuals with albinism are particularly susceptible to heat-related illnesses due to their reduced melanin production, which limits their ability to regulate body temperature.[328]

Households with limited income were more vulnerable to the impacts of extreme heat events. Individuals with pre-existing health conditions such as blood pressure diseases, cardiovascular

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[328] https://www.digest.tz/how-climate-change-exacerbates-risks-for-african-people-living-with-albinism/

disorders, and diabetes are more vulnerable to the impacts of extreme heat. Heatwaves exacerbated their symptoms and increased the risk of heat related illnesses.

Dependence of children, elderly, and disabled people on others for survival made these vulnerable groups susceptible to malnutrition and hunger during extreme heat events.

The capacity of institutions, including local government bodies and relevant organizations, to respond effectively to climate hazards (drought, flood and extreme heat) and provide necessary support to vulnerable populations is often limited. Insufficient resources, coordination, and planning impede effective drought management and adaptation efforts. For example, there are no seed multipliers in Karonga to produce drought resilient crops, and they depend on the central producers to get seed supply.

Waterborne diseases resulting from flood events affected the welfare of people through increased morbidity within the affected community, further exacerbating the impacts of the floods. In evacuation centers, girls and women may be subjected to sexual harassment and exploitation in exchange for access to relief assistance. The vulnerability of displaced individuals increases the risk of gender-based violence.

Negligence to respond to weather warning amongst population is a big challenge. Despite knowing the areas prone to flooding, some households choose to stay in these high-risk areas, increasing their vulnerability to flood-related impacts.

f. Future risk for the district

Certain geographic locations in Karonga are more prone to extreme heat due to their climate and topography. Areas such as Lupembe, Uliwa, and Mlare are particularly susceptible to the impacts of climate hazards such floods, drought and extreme heat.

A detailed assessment should be done to further determine the potential risk and identify the vulnerability of specific project to climate hazards (extreme heat, flood, drought, and dry spells). Certain projects, such as those concerning individual buildings, or infrastructural components such as transformers in the electricity grid, may require a very fine local-scale extreme heat risk assessment, considering, for instance, indoor versus outdoor heat conditions, or sunny versus shaded locations, involving spatial resolutions down to a few meters.

For example, if the project concerns energy production, one might rather need an indicator quantifying cooling energy demand (e.g., cooling degree days). This should be sourced from sector specific analyses in the project area.

Apart from sector-based considerations, it is important to know project's vulnerability to extreme heat hazard which may also arise from indirect sectoral impacts. For example, an industrial production unit may see its operations compromised not only because of local heat stress conditions (affecting labour productivity or component failure), but also because of interrupted transportation and/or energy producing infrastructure affecting its supply lines.

Deforestation and soil degradation contribute to reduced water retention capacity in the landscape, leading to increased surface runoff during periods of limited rainfall. This exacerbates the impacts of drought and dry spells by reducing water availability for agricultural activities and domestic use.

To minimise risk and damage caused by climate hazards the following actions can be done :

Early warning systems which have been established should be strengthened and scaled to provide timely information about climate hazards (flood, extreme heat, drought events) and enable communities to take necessary actions. However, challenges remain in ensuring the uptake and effectiveness of these warning systems, as some households have not taken them seriously.

Some capacity building initiatives which have been conducted should be promoted to enhance the skills and knowledge of disaster response teams. However, further investment in training and resources is needed to improve response efficiency and effectiveness.

Develop comprehensive information and education campaigns to increase understanding of the hazards and their impacts.

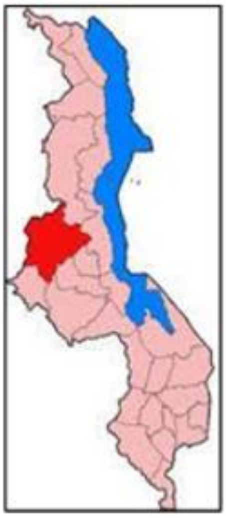
Utilize local leaders, community radio stations, and drama groups to disseminate relevant information about preparedness, response, and adaptive measures.

Empower communities to take ownership of adaptation projects and initiatives. Establish local committees responsible for monitoring and responding to extreme weather events. Strengthen community-based organizations to enable timely and effective responses to weather-based catastrophes.

Enhance awareness and sensitization campaigns: Conduct extensive awareness and sensitization campaigns through local leaders, churches, local radios, and drama groups. These campaigns should focus on educating the community about the risks associated with extreme heat and promoting the adoption of adaptive measures. Enhancing community awareness of floods, extreme heat, and drought is crucial for building resilience. To address this, the following actions are recommended.

Annex 8: Kasungu District – Climate Risk Assessment Report

1. Introduction



Kasungu district, situated in the heart of Malawi's central region, is characterized by its strategic location and unique geographical features. Bordered by Zambia to the west and sharing boundaries with Mchinji, Dowa, and Lilongwe to the south, Mzimba to the north, and Nkhotakota and Ntchisi to the east, Kasungu stands as one of the largest districts in the nation. In the central region, it ranks as the second largest, second only to Lilongwe district.[329] This extensive district boasts an area spanning 7,878 square kilometers and is home to approximately 842,953 people, resulting in a population density of 105 individuals per square kilometer.[330]

Kasungu's economic landscape is predominantly shaped by agriculture, livestock production, fishing, and small-scale trading. Maize reigns as the dominant crop, accompanied by tobacco, groundnuts, cassava, soya beans, sweet potatoes, and common beans. Tobacco has been predominantly the main cash crop in the district. However, the crop has recently been subjected to wide fluctuations in prices on the auction floors. In contrast, soya beans and beans, previously overlooked as cash crops, are now emerging as significant contributors to the local economy, offering a buffer in times of uncertainty regarding tobacco prices and its future.

Despite its agricultural potential, Kasungu district has grappled with food insecurity at the household level, particularly in certain EPAs (Extension Planning Areas). The situation reached a critical juncture during the 2015/2016 farming season.[331] As the population continued to grow, food production remained relatively stagnant. Several factors contributed to this conundrum, including poor production technologies, limited access to necessary farming inputs, depleted soil fertility, and unfavorable climatic conditions. These climatic challenges encompassed late onset of rains, early cessation of rains, erratic rainfall patterns, and prolonged dry spells, all of which exacerbated food insecurity.[332] Poverty remains a persistent issue in Kasungu, with an ultra-poverty rate of 26.2% recorded in 2019/2020. The district's heavy reliance on agriculture as its economic backbone underscores the importance of addressing poverty-related concerns. Alarmingly, approximately 67% of the population lives below the national poverty line, as revealed in the Malawi poverty report of 2020.

329 https://global-uploads.webflow.com/6061a9d807f5368139d1c52c/610b26ade478c94f0e0c6cc4_Cleared-Kasungu-SEP-02-June-2018.pdf
330http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2018/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report.pdf
331 KASUNGU DISTRICT SOCIO-ECONOMIC PROFILE 2017-2022
332 KASUNGU DISTRICT SOCIO-ECONOMIC PROFILE 2017-2022

Kasungu district is no stranger to climatic vagaries, given its subtropical climate. It experiences a rainy season from November to April, followed by a dry season from May to October. However, this climatic normalcy is frequently disrupted by climate hazards such as floods, droughts, prolonged dry spells, strong winds, and pest infestations. These challenges pose significant threats to agricultural production and food security in the region. Notably, Kasungu faces key climate change risks, including rising temperatures, more frequent and severe droughts, and shifting rainfall patterns, all of which cast a shadow over agricultural yields and the rural livelihoods dependent on farming. Additionally, it is worth noting that Kasungu, while not prone to large-scale flooding, still contends with localized flooding along the Dwangwa, Rusa, and Bua Rivers. To navigate these pressing issues, it is important to enhance the resilience and adaptive capacity of Kasungu's communities. By reducing vulnerability to climate change impacts, the district can chart a course toward sustainable development and a more secure future. These sporadic events underscore the multifaceted challenges that must be addressed in the pursuit of a comprehensive climate risk assessment for Kasungu district.

2. Hazard Focus

a. Storm – Extreme Rain and Wind

In Kasungu District, climate-related hazards are a significant concern, with a particular focus on storms characterized by extreme rainfall and strong winds. These storms pose considerable risks, often resulting in flash floods and causing extensive damage to infrastructure, crops, and livestock. To better understand the implications of this hazard, we must delve into its projection and examine specific examples of its impact. To illustrate the gravity of this hazard, we can refer to recent events in Kasungu District. In 2023, a devastating hailstorm swept through the region, resulting in substantial losses for local farmers. Specifically, more than 600 farmers experienced the loss of vast hectares of various crops. Villages such as Nyambo, Mkombe, Katondo, and Machinyira bore the brunt of the storm's fury.[333] According to the assessment report for Kasungu District, the affected crops encompassed staples such as Maize, Soya, Tobacco, Beans, Tomatoes, Potatoes, and Groundnuts.[334] The scale of destruction was staggering, with 357.4 hectares of Maize, 502.4 hectares of Soya, 150 hectares of Tobacco, 194 hectares of Beans, 4 hectares of Tomatoes, 6 hectares of Potatoes, and 85 hectares of Groundnuts devastated by the disaster.[335]

The impact extended beyond agriculture, as the storm also wreaked havoc on residential structures. The Malawi government confirmed that the heavy rains and hailstorms in Kasungu District, Central Region, led to damage or destruction of 664 houses. [336]This occurred during the rainfall and flooding episodes that occurred between 07 and 08 January 2016, affecting numerous villages including Mtoso,

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333 https://www.capitalradiomalawi.com/2023/02/20/over-1-200-hectors-of-crops-lost-in-kasungu-hailstorm/#:~:text=More%20than%20600%20farmers%20have%20lost%20huge%20hectares%20of%20various%20crops%20in%20Kasungu%20district%20due%20to%20weather%20related%20disasters%20in%20the%20past%20weeks.
334 https://www.capitalradiomalawi.com/2023/02/20/over-1-200-hectors-of-crops-lost-in-kasungu-hailstorm/#:~:text=607%20farmers%20from,of%20ground%20nuts.
335 https://www.capitalradiomalawi.com/2023/02/20/over-1-200-hectors-of-crops-lost-in-kasungu-hailstorm/#:~:text=607%20farmers%20from,of%20ground%20nuts.
336 https://floodlist.com/africa/malawi-floods-central-northern-regions-january-2016#:~:text=the%20Malawi%20government,Kamphako%20and%20Mphamba.

Chisinga, Chatanga, Zombo, Chitsulu, Matondo, Saiko, Kakhuza, Longwe, Kamphako, and Mphamba.[337] In addition to housing, the storm's fury extended to crops, further exacerbating the challenges faced by local communities. Approximately 1611 hectares of crops were damaged, with specific losses including 1,255 hectares of maize, 224 hectares of soya, 100 hectares of tobacco, and 32 hectares of beans.[338]

b. Flood

Floods pose a major climate change threat in Kasungu District. Increased extreme rainfall and urbanization are projected to elevate flood risk (CEPA, 2018). Recent floods have displaced communities, damaged infrastructure, and contaminated water sources.[339] In January 2016, heavy rains and hailstorms destroyed or damaged 664 houses in Kasungu, leaving many homeless[340] Over 1,600 hectares of cropland were also damaged, including maize (1,255 ha), soybeans (224 ha), tobacco (100 ha) and beans (32 ha), causing substantial food security impacts.[341] Roads, bridges and other infrastructure have been repeatedly flooded, disrupting transportation networks. Floodwaters carry pollutants from roads, farms and urban areas into waterways like the Bua River, degrading quality and endangering human health. With over 80% of Kasungu's population dependent on smallholder rain-fed agriculture, frequent flood damage to crops and infrastructure threatens livelihoods and food security. Urgent adaptation priorities include upgrading urban and road drainage systems, strengthening early warning systems, constructing protective infrastructure like embankments, and improving flood-resistant standards for infrastructure, housing and agriculture.

c. Extreme heat

Kasungu District currently experiences some periods of increase in temperature, which can adversely impact human health, agriculture, and livestock. These heats are projected to increase in frequency and severity with climate change. [342] Prolonged extreme heat puts vulnerable groups like children and the elderly at higher risk of heat exhaustion and heat stroke. Crop yields for maize, tobacco and other staples also decline sharply under extreme temperatures, exacerbating food insecurity. Livestock productivity similarly suffers due to heat stress.

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337 https://floodlist.com/africa/malawi-floods-central-northern-regions-january-2016#:~:text=the%20Malawi%20government,Kamphako%20and%20Mphamba.

338 https://floodlist.com/africa/malawi-floods-central-northern-regions-january-2016#:~:text=The%20rains%20also%20damaged%20about%201611%20hectares%20of%20crops%2C%20including%201%2C255%20hectares%20of%20maize%2C%20224%20hectares%20of%20soya%2C%20100%20hectares%20of%20tobacco%2C%20and%2032%20hectares%20of%20beans.

339 https://cepa.org.mw/Library/climate-change/Likely%20Impacts%20of%20Climate%20on%20Water%20Availability.pdf

340 https://floodlist.com/africa/malawi-floods-central-northern-regions-january-2016#:~:text=the%20Malawi%20government%20confirmed%20that%20heavy%20rains%20and%20hailstorms%20have%20damaged%20or%20destroyed%20664%20houses%20in%20Kasungu%20District%2C%20Central%20Region.

341 https://floodlist.com/africa/malawi-floods-central-northern-regions-january-2016#:~:text=the%20Malawi%20government%20confirmed%20that%20heavy%20rains%20and%20hailstorms%20have%20damaged%20or%20destroyed%20664%20houses%20in%20Kasungu%20District%2C%20Central%20Region.

342 https://www.irishaid.ie/media/irishaid/allwebsitemedia/30whatwedo/climatechange/Malawi-Country-Climate-Action-Reports-for-2016.pdf

Kasungu's hot season lasts 2-3 months from late September to November, with average highs above 83°F.[343] The hottest month is November, when average high temperatures reach 85°F and lows 68°F.[344] But these averages mask more intense increase in temperature, like in October 2022 when Kasungu recorded a high of 104°F, its hottest temperature ever. With heat extremes projected to rise, preparedness measures are essential, including public health campaigns, heat-tolerant crops, livestock sheds, and climate information to warn vulnerable groups.

d. Drought/dry spells

Kasungu is highly vulnerable to drought, which has become more frequent and intense in recent decades.[345] cording to the Malawi National Climate Change Management Policy.[346] According to the Malawi National Climate Change Management Policy (2016), Kasungu experiences frequent and severe droughts that severely impact various sectors including agriculture, water, forestry, livestock, fisheries, infrastructure, and human health.[347] These drought events can lead to water scarcity, reduced crop yields, and food insecurity.[348] Projections indicate the duration and severity of droughts will increase in Kasungu, resulting in prolonged water stress, crop failure, and heightened vulnerability to food shortages (Government of Malawi, 2016). For example, dry spells in the 2012/2013 growing season caused widespread crop wilting across the district, with maize yields declining by 16%.[349]

The 2015-16 El Niño drought highlighted Kasungu's susceptibility, as crop failure left half the district needing food aid.[350] Negative coping strategies like selling livestock assets, reducing meals, and transactional sex rose.[351] Gender-based violence also increased as men abandoned families and girls were sexually exploited for food.[352] Health and education services were compromised. Developing climate-resilient farming techniques and social safety nets is essential to protect lives and livelihoods during future droughts. Another extreme case is shown in the Simlemba wetland in Kasungu, as it falls with a drought-prone geographic area. Local communities extensively utilize the wetland for winter cropping of vegetables like cabbage, tomatoes and onions to adapt to climate change impacts like

343 https://weatherspark.com/y/97537/Average-Weather-in-Kasungu-Malawi-Year-Round
344 https://weatherspark.com/y/97537/Average-Weather-in-Kasungu-Malawi-Year-Round
345 Chikabvumbwa SR, Salehnia N, Manzanas R, Abdelbaki C, Zerga A. Assessing the effect of spatial-temporal droughts on dominant crop yield changes in Central Malawi. Environ Monit Assess. 2022 Jan 7;194(2):63. doi: 10.1007/s10661-021-09709-4. PMID: 34993655.
346 https://www.irishaid.ie/media/irishaid/allwebsitemedia/30whatwedo/climatechange/Malawi-Country-Climate-Action-Reports-for-2016.pdf
347 https://cepa.org.mw/Library/government-publications/national-climate-change-management-policy-2016/view
348 CEPA (Centre for Environmental Policy and Advocacy). (2010). Likely Impacts of Climate Change on Water Availability: Case Study of T/A Simlemba in Kasungu. Blantyre, Malawi: CEPA.
349 https://fews.net/southern-africa/malawi/food-security-outlook/april-2013#:~:text=Compared%20to%20the%202011/12%20season,yields%20in%20these%20areas%20this%20season.
350 https://reliefweb.int/report/malawi/el-ni-o-drought-forces-malawi-declare-food-emergency-urgent-action-needed
351 https://openknowledge.worldbank.org/entities/publication/c00c87c1-2da4-5f20-9029-63ecedc64e43
352 https://openknowledge.worldbank.org/entities/publication/c00c87c1-2da4-5f20-9029-63ecedc64e43

droughts.[353] However, a majority of households in this area are resource-poor smallholder farmers vulnerable to degraded natural resources, food and economic insecurity due to low agricultural productivity, increasingly frequent droughts, and limited assets.[354] Developing climate-resilient agro-ecological practices in the wetlands in Kasungu district could improve food security for vulnerable farmers in the face of mounting drought risks.

3. Sectoral impact analysis of extreme events

a. Agriculture - crop production

Over 80% of Malawi's population depends on rain-fed smallholder agriculture, which contributes 29% of GDP. [355] Maize is the dominant staple crop, covering 60% of cropland (FAO, 2018). As Malawi's top maize-producing district, Kasungu is highly vulnerable to maize losses from recurrent drought.[356] Climate projections for the district forecast rising temperatures and altered precipitation patterns that could reduce yields of key crops like maize, soybeans, groundnuts by 2050. [357] Kasungu ADD is estimated to experience a reduction of 48 kilograms per annum in agricultural production due to climate change. [358]

These projected declines in crop productivity will likely exacerbate food insecurity and childhood stunting, which remain major challenges in Kasungu and across Malawi. Adaptation efforts are urgently needed to strengthen the drought resilience of smallholder farming systems. Some promising interventions include developing and distributing drought-tolerant, early maturing crop varieties, crop diversification, conservation agriculture techniques, and expanding irrigation infrastructure where feasible. integrated soil fertility management is also critical to reverse nutrient depletion and erosion exacerbated by unsustainable practices and more frequent droughts.[359]

b. **Agriculture - livestock**

Livestock production is an important livelihood strategy providing food, income and savings for Kasungu households, particularly wealthier farmers.[360] But recurrent drought takes a heavy toll on the livestock sector by degrading pastures and rangelands, forcing distress sales and higher mortality rates.

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353 https://cepa.org.mw/Library/climate-change/Policy%20Brief%20on%20the%20Current%20National%20Policies%20and%20Strategies%20Related%20to%20Wetlands%20Use%20and%20Climate%20Change.pdf
354 https://cepa.org.mw/Library/climate-change/Likely%20Impacts%20of%20Climate%20on%20Water%20Availability.pdf
355 https://www.tiyeni.org/news/2019/80-of-malawis-population-depends-on-rainfed-subsistence-agriculture/#:~:text=Agriculture%20remains%20the%20largest%20economic%20activity%20contributing%2028.7%25%20of%20GDP%20and%20more%20than%2080%25%20of%20export%20earnings.
356 https://www.tiyeni.org/news/2019/80-of-malawis-population-depends-on-rainfed-subsistence-agriculture/#:~:text=Agriculture%20remains%20the%20largest%20economic%20activity%20contributing%2028.7%25%20of%20GDP%20and%20more%20than%2080%25%20of%20export%20earnings.
357 https://www.ifad.org/documents/38714170/42164624/climate_analysis_malawi.pdf/89454253-8418-fe90-aa77-78aa82401557?t=1606831139000
358 https://www.ifad.org/documents/38714170/42164624/climate_analysis_malawi.pdf/89454253-8418-fe90-aa77-78aa82401557?t=1606831139000
359 https://www.ifad.org/en/web/operations/-/project/1100000158
360 https://core.ac.uk/download/pdf/132631021.pdf

Targeted interventions to bolster climate resilience for livestock producers in Kasungu include integrating drought-tolerant fodder crops like *lablab purpureus* into pasture lands to improve food security, along with livestock insurance products to help farmers recover from asset losses. Improving access to climate information services and early warning systems is also essential to give pastoralists more lead time to prepare for droughts.

c. Forestry including forest fires and impacts on forest productivity

Forestry plays a crucial role in Kasungu District. providing vital ecosystem services including timber, fuelwood, food sources and conservation of water resources and biodiversity.[361] But Kasungu's forests are increasingly threatened by overexploitation, agricultural expansion and more frequent, severe droughts. From 2001-2022, Kasungu lost 1,030 ha of tree cover, with over 50% concentrated near the Traditional Authority of Kaluluma.[362] Deforestation reduces rainfall infiltration and increases runoff and soil erosion, compounding the impacts of drought.[363]

Drought also heightens the risk of destructive forest fires, which are projected to increase in frequency and intensity with climate change (Government of Malawi, 2016).[364] Integrated fire and drought

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361https://www.researchgate.net/publication/264410475_STATUS_OF_FORESTS_AND_TREE_MANAGEMENT_I
N_MALAWI_A_Position_Paper_Prepared_for_the_Coordination_Union_for_Rehabilitation_of_the_Environme
nt_CURE

362https://www.globalforestwatch.org/dashboards/country/MWI/9/?category=fires&location=WyJjb3VudHJ5I
iwiTVdJIiwiOSJd&map=eyJjZW50ZXIiOnsibGF0IjotMTQuMDQ0MDg4NDc4MDU4NzE1LCJsbmciOjMzLjc2MTY0O
Tk5OTk3MzAyNH0sInpvb20iOjYuOTk5MTgyNzcyNTI5MzM0LCJjYW5Cb3VuZCI6dHJ1ZSwiZGF0YXNldHMiOlt7ImR
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cnVlfSx7ImRhdGFzZXQiOiJ0cmVlLWNvdmVyLWxvc3MiLCJsYXllcnMiOlsidHJlZS1jb3Zlci1sb3NzIl0sIm9wYWNpdH
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%20and%20lasts%20around%2016%20weeks.%20There%20were%20106%20VIIRS%20fire%20alerts%20report
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ng%20high%20confidence%20alerts%20only.%20This%20is%20low%20compared%20to%20previous%20years
%20going%20back%20to%202012.

363https://www.globalforestwatch.org/dashboards/country/MWI/9/?category=fires&location=WyJjb3VudHJ5I
iwiTVdJIiwiOSJd&map=eyJjZW50ZXIiOnsibGF0IjotMTQuMDQ0MDg4NDc4MDU4NzE1LCJsbmciOjMzLjc2MTY0O
Tk5OTk3MzAyNH0sInpvb20iOjYuOTk5MTgyNzcyNTI5MzM0LCJjYW5Cb3VuZCI6dHJ1ZSwiZGF0YXNldHMiOlt7ImR
hdGFzZXQiOiJwb2xpdGljYWwtYm91bmRhcmllcyIsImxheWVycyI6WyJkaXNwdXRlZC1wb2xpdGljYWwtYm91bmR
hcmllcyIsInBvbGl0aWNhbC1ib3VuZGFyaWVzIl0sImJvdW5kYXJ5Ijp0cnVlLCJvcGFjaXR5IjoxLCJ2aXNpYmlsaXR5Ijp0
cnVlfSx7ImRhdGFzZXQiOiJ0cmVlLWNvdmVyLWxvc3MiLCJsYXllcnMiOlsidHJlZS1jb3Zlci1sb3NzIl0sIm9wYWNpdH
kiOjEsInZpc2liaWxpdHkiOnRydWUsInBhcmFtcyI6eyJ0aHJlc2hvbGQiOjMwLCJ2aXNpYmlsaXR5Ijp0cnVlfX1dfQ%3
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%20and%20lasts%20around%2016%20weeks.%20There%20were%20106%20VIIRS%20fire%20alerts%20report
ed%20between%2031st%20of%20October%202022%20and%2030th%20of%20October%202023%20consideri
ng%20high%20confidence%20alerts%20only.%20This%20is%20low%20compared%20to%20previous%20years
%20going%20back%20to%202012.

364https://www.globalforestwatch.org/dashboards/country/MWI/9/?category=fires&location=WyJjb3VudHJ5I
iwiTVdJIiwiOSJd&map=eyJjZW50ZXIiOnsibGF0IjotMTQuMDQ0MDg4NDc4MDU4NzE1LCJsbmciOjMzLjc2MTY0O
Tk5OTk3MzAyNH0sInpvb20iOjYuOTk5MTgyNzcyNTI5MzM0LCJjYW5Cb3VuZCI6dHJ1ZSwiZGF0YXNldHMiOlt7ImR
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hcmllcyIsInBvbGl0aWNhbC1ib3VuZGFyaWVzIl0sImJvdW5kYXJ5Ijp0cnVlLCJvcGFjaXR5IjoxLCJ2aXNpYmlsaXR5Ijp0
cnVlfSx7ImRhdGFzZXQiOiJ0cmVlLWNvdmVyLWxvc3MiLCJsYXllcnMiOlsidHJlZS1jb3Zlci1sb3NzIl0sIm9wYWNpdH
kiOjEsInZpc2liaWxpdHkiOnRydWUsInBhcmFtcyI6eyJ0aHJlc2hvbGQiOjMwLCJ2aXNpYmlsaXR5Ijp0cnVlfX1dfQ%3
D%3D#:~:text=In%20Kasungu%20the%20peak%20fire%20season%20typically%20begins%20in%20late%20July

management should be priorities to improve the climate resilience of Kasungu's threatened forests. Reforestation efforts with native species are also urgently needed, along with stronger policies to curb deforestation and agricultural encroachment. In Kasungu the peak fire season typically begins in late July and lasts around 16 weeks. There were 106 VIIRS fire alerts reported between 31st of October 2022 and 30th of October 2023 considering high confidence alerts only. This is low compared to previous years going back to 2012.[365]

d. Fisheries (capture and aquaculture)

Capture fisheries from rivers including the Rusa, Bua and Dwangwa provide vital sources of income, nutrition and food security for communities across Kasungu.[366] Aquaculture production is also growing in the district. But Kasungu's fisheries face escalating threats from recurrent drought and higher temperatures associated with climate change. Projections indicate declining water quality, habitat and fish populations under increased water stress and warming.[367] Targeted adaptation measures are essential to build resilience, such as promoting water-efficient fish farming methods, integrating drought-tolerant fish species, and strengthening early warning systems and climate information services for fishing communities. Catch limits and seasonal fishing bans during drought may also be warranted to prevent overexploitation of stressed fisheries.

e. Infrastructure

Kasungu's roads, bridges, buildings and other critical infrastructure face escalating risks of damage and disruption from climate extremes like floods, storms, and drought.[368] These hazards are projected to increase in frequency and intensity with climate change. Recent examples showcase Kasungu's

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%20and%20lasts%20around%2016%20weeks.%20There%20were%20106%20VIIRS%20fire%20alerts%20reported%20between%2031st%20of%20October%202022%20and%2030th%20of%20October%202023%20considering%20high%20confidence%20alerts%20only.%20This%20is%20low%20compared%20to%20previous%20years%20going%20back%20to%202012.

365https://www.globalforestwatch.org/dashboards/country/MWI/9/?category=fires&location=WyJjb3VudHJ5IiwiTVdJIiwiOSJd&map=eyJjZW50ZXIiOnsibGF0IjotMTQuMDQ0MDg4NDc4MDU4NzE1LCJsbmciOjMzLjc2MTY0OTk5OTk3MzAyNH0sInpvb20iOjYuOTk5MTgyNzcyNTI5MzM0LCJjYW5Cb3VuZCI6dHJ1ZSwiZGF0YXNldHMiOlt7ImRhdGFzZXQiOiJwb2xpdGljYWwtYm91bmRhcmllcyIsImxheWVycyI6WyJkaXNwdXRlZC1wb2xpdGljYWwtYm91bmRhcmllcyIsInBvbGl0aWNhbC1ib3VuZGFyaWVzIl0sImJvdW5kYXJ5Ijp0cnVlLCJvcGFjaXR5IjoxLCJ2aXNpYmlsaXR5Ijp0cnVlfSx7ImRhdGFzZXQiOiJ0cmVlLWNvdmVyLWxvc3MiLCJsYXllcnMiOlsidHJlZS1jb3Zlci1sb3NzIl0sIm9wYWNpdHkiOjEsInZpc2liaWxpdHkiOnRydWUsInBhcmFtcyI6eyJ0aHJlc2hvbGQiOjMwLCJ2aXNpYmlsaXR5Ijp0cnVlfX1dfQ%3D%3D#:~:text=In%20Kasungu%20the%20peak%20fire%20season%20typically%20begins%20in%20late%20July%20and%20lasts%20around%2016%20weeks.%20There%20were%20106%20VIIRS%20fire%20alerts%20reported%20between%2031st%20of%20October%202022%20and%2030th%20of%20October%202023%20considering%20high%20confidence%20alerts%20only.%20This%20is%20low%20compared%20to%20previous%20years%20going%20back%20to%202012.

366 https://landmatrix.org/media/uploads/scotland-malawipartnershiporgdocuments68-kasungusep2006-2009finalpdf.pdf

367 https://www.cif.org/sites/cif_enc/files/ppcr_strategic_program_for_climate_resilience_for_malawi.pdf

368 https://reliefweb.int/report/malawi/malawi-severe-weather-metmalawi-department-disaster-management-affairs-dodma-floodlist-echo-daily-flash-4-january-2023#:~:text=In%20the%202022%2D2023%20rainy%20season%20(which%20started%20in%20November)%2C%20heavy%20rains%2C%20strong%20winds%2C%20and%20thunderstorms%20have%20affected%2024%20councils%20of%20Malawi%2C%20causing%20floods%2C%20and%20severe%20weather%2Drelated%20incidents%20that%20resulted%20in%20casualties%20and%20damage.

vulnerability. In the 2022-2023 rainy season, heavy rains, strong winds and thunderstorms affected 24 districts in Malawi including Kasungu, triggering widespread floods that damaged key infrastructure. [369] Over 60 roads were impacted across the Central Region, hampering transport and mobility. Bridges and culverts were also washed away, further isolating communities. In Kasungu, the Lilongwe-Mchinji Road was temporarily closed after floodwaters made it impassable, disrupting a major trade route (Malawi24, 2022). Buildings and homes have also been repeatedly damaged during storms. Upgrading vulnerable infrastructure to climate-resilient designs is urgently needed to withstand worsening extremes and maintain essential services in Kasungu.

f. Water

Kasungu depends on surface water resources like rivers, streams and wetlands for irrigation, domestic and industrial use. [370] Reduced rainfall and higher rates of evaporation lower river flows and groundwater levels. [371] Small streams and wetlands can dry up completely during severe drought.[372] Water quality declines as pollution concentrations increase when water volumes are low.[373] Overall, water scarcity during drought limits usage for irrigation, domestic, industrial and ecological purposes.

g. Human Health

Climate change is exacerbating health risks in Kasungu District, Malawi through more frequent extreme weather events like droughts, floods, and heatwaves. Prolonged droughts can lead to water scarcity and contamination, increasing illnesses like diarrhea and cholera. [374] Food insecurity and malnutrition also rise, further weakening immune systems. Respiratory issues emerge from dust storms and air pollution. Mental health problems result from livelihood and income losses.

Malaria is more prevalent in highland areas of Kasungu, Ntchisi and Rumphi as warmer temperatures allow malaria-carrying mosquitoes to thrive.[375] he most urgent climate change-related health risks in Malawi are increased malaria, diarrhea, food insecurity and malnutrition. Displacement to urban areas may also increase health issues. Overall, climate stresses influence many diseases and raise mental health challenges.[376]

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369 https://reliefweb.int/report/malawi/malawi-severe-weather-metmalawi-department-disaster-management-affairs-dodma-floodlist-echo-daily-flash-4-january-2023#:~:text=In%20the%202022%2D2023%20rainy%20season%20(which%20started%20in%20November)%2C%20heavy%20rains%2C%20strong%20winds%2C%20and%20thunderstorms%20have%20affected%2024%20councils%20of%20Malawi%2C%20causing%20floods%2C%20and%20severe%20weather%2Drelated%20incidents%20that%20resulted%20in%20casualties%20and%20damage.

370 Msusa, H. (2011). Sustainable Utilization of Wetlands for Food Security: A Case Study of the Simulemba Traditional Authority in the Kasungu District of Malawi. Journal of Developments in Sustainable Agriculture, 6, 86-100.

371 Msusa, H. (2011). Sustainable Utilization of Wetlands for Food Security: A Case Study of the Simulemba Traditional Authority in the Kasungu District of Malawi. Journal of Developments in Sustainable Agriculture, 6, 86-100.

372 CEPA (Centre for Environmental Policy and Advocacy). (2010). Likely Impacts of Climate Change on Water Availability: Case Study of T/A Simulemba in Kasungu. Blantyre, Malawi: CEPA.

373 Government of Malawi (GoM). (2010). Malawi Fourth National Report to the Convention on Biological Diversity. Lilongwe, Malawi: Ministry of Natural Resources, Energy and Environment.

374 https://pumpaid.org/malawi-cholera-outbreak-delays-school-reopening/

375 https://www.climatecentre.org/wp-content/uploads/RCRC_IFRC-Country-assessments-Malawi_Final3.pdf

376 https://www.climatecentre.org/wp-content/uploads/RCRC_IFRC-Country-assessments-Malawi_Final3.pdf

Risk Summary

Kasungu District faces considerable climate change risks that threaten key sectors and community livelihoods. Key hazards include destructive storms, floods, extreme heat, and droughts/dry spells, which are projected to rise in frequency and severity. These extremes pose risks of infrastructure damage, agricultural losses, fisheries declines, water scarcity, forest degradation, and escalating health issues. With over 80% reliance on vulnerable rain-fed smallholder agriculture, recurrent droughts represent a major threat to food security, incomes, and rural livelihoods in Kasungu. Livestock productivity also suffers. Deforestation and increased aridity heighten risks of destructive wildfires during dry periods. Flooding threatens contamination of water bodies vital for domestic use, irrigation, and fisheries. Disease prevalence is likely to rise with warmer temperatures, water scarcity, and malnutrition. Overall, climate projections paint an uncertain future for Kasungu, with potential declines in staple crop yields, pasture productivity, surface water availability, and increasing infrastructure damage. Urgent adaptation efforts across sectors are essential to counter escalating climate risks and strengthen community resilience.