

Climate and Health Vulnerability Assessment



ETHIOPIA

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Cover image: In Ethiopia, women and young village girls collect water from a rain water pool which is purified before use with tablets. Shutterstock/Martchan.

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LIST OF ABBREVIATIONS

CHVA	Climate and Health Vulnerability Assessment
COPD	Chronic Obstructive Pulmonary Disease
CRGE	Climate Resilient Green Economy
CRHS	Climate-resilient health system
CSA	Central Statistics Agency
DALYs	Disability-adjusted Life Years
DHIS2	District Health Information System (2)
EMI	Ethiopian Meteorological Institute
ENSO	El Niño-Southern Oscillation
EPA	Environmental Authority
EPHI	Ethiopian Public Health Institute
GCM	General circulation models
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GTP II	Second Growth and Transformation Plan
HAP	Household air pollution
HEP	Health Extension Programme
HCF	Healthcare facility
INDC	Intended Nationally Determined Contributions
LDC	Least Developed Countries
NCDs	Non-communicable Diseases
NDC	Nationally Determined Contributions
NHAP	National Health Adaptation Plan
NTDs	Neglected Tropical Diseases
MoH	Ministry of Health
PHEM	Center for Public Health Emergency Management
SAM	Severe Acute Malnutrition
SOP	Standard Operating Procedures
SSP	Shared Socio-economic Pathways
TWG	Technical Working Group
UHI	Urban Heat Island
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation
VBD	Vector-borne disease
WaSH	Water, Sanitation, and Hygiene
WBG	World Bank Group
WHO	World Health Organization
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Ethiopia faces significant climate-related challenges that will directly influence population health outcomes. Climate change, coupled with human-induced health stressors, exacerbates existing health burdens, and creates new health risks. Changes in temperature and precipitation patterns affect the country and burden a variety of climate-sensitive health risks while simultaneously impacting the functioning and capacity of Ethiopia's health system. Challenges that increase Ethiopia's vulnerability to adverse health outcomes associated with climate change include the wide range of climate hazards that affect the country due to its strong dependency on rainfed agriculture, which is susceptible to regular climatic shocks, ongoing population growth, and chronic and widespread undernutrition.

CLIMATOLOGY

Mean annual **temperatures** have been increasing, with the highest rates of warming observed in the central and highland areas and are projected to increase significantly in the eastern regions of Somali and Afar and the western region of Gambela. **Precipitation**, on the contrary, has been declining with significant year-to-year variations. Future projections of precipitation, however, show a slight increase in national average annual precipitation rates as short and intense rainfall events increase in frequency. Continued warming trends, however, will likely exacerbate seasonal and regional declines in rainfall, further increasing the intensity and frequency of **drought** events and affecting the Tigray, Afar, and Somali regions. The Afar and Somali regions, along with Gambela and Beneshangul Gumu, will also be affected by **extreme heat** (days at $> 35^{\circ}\text{C}$ and nights at $> 20^{\circ}\text{C}$). High deforestation rates and increased extreme rainfall will continue to trigger soil erosion, reduce soil fertility, and increase **rainfall-trigger landslides**, particularly in the eastern Tigray region, along the Amhara region.

CLIMATE-RELATED HEALTH RISKS

Some health outcomes affected by climatic factors will be of extreme concern. The Afar, Somali, and Gambela regions are likely to experience increases in the number of hot days ($\text{TMax} > 35^{\circ}\text{C}$) and tropical nights ($> 20^{\circ}\text{C}$) exposing roughly 13.3 million people to potentially **life-threatening temperatures** with implications on the health of those populations, particularly vulnerable groups such as pregnant women, children under five years of age, people over 65 years. **Food insecurity**, for example, will continue due to acute shocks and chronic changes in climate projections. Precipitation is projected to decrease, worsening drought and consequently affecting those who rely on rain-fed agriculture and livestock production. Many southern and south-eastern pastoral areas experienced lower-than-normal pasture and water availability, which will cause significant food and income loss. Smallholder farmers, who represent most of the rural population and produce more than 90 percent of total agricultural output,

will be severely impacted, especially in areas already overburdened with high **undernutrition**, such as Tigray, Afar, and Somali regions. Ethiopia has one of the highest levels of food insecurity in the world, and children (<5 years) will continue to be one of the most affected groups. The Amhara, Benishangul-Gumuz, Affar, and Dire Dawa regions are the most affected by **child stunting**, whereas **wasting** imposes the heaviest burden in Somali, Afar, and Gambela areas. Child mortality continues to be high, particularly in Addis Ababa and Afar. Additionally, climatic shocks and compounding factors, such as conflict, desert locust invasions, and the COVID-19 pandemic, continue to drive up food and nutrition insecurity and prices of staple foods in Ethiopia, increasing levels of **malnutrition**, already affecting an estimated 18 million people.

Increases in the intensity of rainfall events will continue to cause flash, groundwater, and sewer flooding, worsening hazards for human health. The East Africa sub-region is projected to be the worst impacted during and after El Niño events, increasing **cholera** deaths, particularly in children below 15 years old. Projected increases in warm temperatures, increases in intense periods of precipitation, and shifting patterns of rainfall will increase the proliferation and persistence of pathogens, making managing and sustained control of outbreaks challenging. Addis Ababa, for example, already experiences the most precipitation in the country, and with projected increases in rainfall, mean temperatures, and population, will likely experience **increased episodes of diarrheal diseases**. More intense droughts are also associated with reduced water quality and disease outbreaks.

The lack of fresh rain during droughts prevents the opportunity to flush out stagnant waters. Because of the overlapping feature of the epidemiology of **dengue fever and malaria**, vectors

of both diseases breed in small water pools in discarded utensils adjacent to households. Since 2013, dengue fever cases have increased due to repeated outbreaks reported in eastern Ethiopia, with peak high malaria prevalence observed between September and November. Slight increases in the number of consecutive dry days are projected in the Somali region, particularly between the months of September-October, which are historically considered high malaria transmission months. Suitability for malaria vectors through mid-century will remain unchanged throughout the country as projected temperature increases will not exceed the thermal tolerance of malaria vector species. Only in the Somali region, during the 2030s and 2050s, will temperature increase limit vector survival; however, hot spots will remain, particularly in Hadiya, Metekel, and South Gondar districts.

Extreme weather events are becoming more frequent and intense in Ethiopia, potentially leading to an increased risk of elevated rates of **mental disorders**. Moreover, research shows that mental health conditions attributed to extreme weather events increased, impacting a larger fraction of the population affected by natural disasters. The destruction of landscape, such as through severe flash flooding, diminishes the sense of belonging and comfort people derive from their connectedness to the land.

ADAPTIVE CAPACITY OF THE HEALTH SYSTEM

The Government of Ethiopia is aware of the potential negative impacts of climate change and has been actively developing policies and plans to support mitigation and adaptation actions, as well as signing onto international and regional initiatives. **Health** is highlighted as a priority area, second in number only to agriculture and climate service/disaster risk reduction, with six **adaptation**

interventions focusing on vector-borne diseases (malaria), water-borne diseases (cholera), and adequately resourced healthcare facilities with safe water and sanitation and reliable electricity. Ethiopia also has social protection policies to deal with the post-recovery of disaster victims through establishing a community-based social security fund. At the sub-national, however, **health-focused climate change adaptation planning is limited.**

The MoH has made strides to enhance its response to extreme weather events and other public health emergencies. Still, many existing **health facilities are not equipped** with the needed equipment, trained health professionals, and essential infrastructure, such as safe and reliable water supply, electricity, means of communication, and adequate medical storage conditions, leaving many healthcare facilities exposed to climate change-related disasters. There are also issues with procurement, maintenance, and inventory management of **medical equipment**, along with a gap in testing the efficacy of generic drugs produced in Ethiopia due to a lack of bioequivalence centers.

Simultaneously, climate change impacts the **health workforce** and may affect their ability to reach the facility and be unable to respond to climate hazards. Additionally, the healthcare system lacks enough medical doctors and nurses, particularly in rural or remote areas. Current salaries of health workers are low and with irregular payments. Health workers also lack adequate labor conditions. This has triggered the out-migration of skilled health workers. Although **specialty training programs** have been developed to enhance retention strategies for the nursing workforce, these have proved insufficient. There are no details if these programs integrated climate-related health risks. There are no reports on the number of psychiatrists, psychologists, or nurses with mental health training. Additionally, the Ministry of Health has

not yet implemented mental health services as part of integrated services. Identified barriers to implementation include low political commitment, shortage of resources, non-functional referral system, lack of interest from private health service organizations, attitudinal problems from the society and service providers, and lack of consistent reporting system of the mental health problems.

Overall, Ethiopia has seen significant advancements in health service delivery in the last two decades, resulting in improvements in several health outcomes. However, **access to health services** tends to disproportionately benefit those with greater economic means or higher levels of education, despite governmental efforts to overcome financial barriers, such as subsidization of more than 80 percent of the cost in public health facilities and community-based insurance schemes. Over the last two decades, total **health expenditure** has been low and declining, while out-of-pocket expenditure has been higher than public health expenditure. Ethiopia has scaled up a community-based health insurance program, but risk pooling does not account for climate and health-related risks. Access to healthcare can still be challenging for some areas of the country, with thousands of people living over 150 km away from a hospital, such as in the Oromia region.

Climate financing is low and shows a huge gap in budgeted versus actual spending. The majority of financing for the climate is focused on adaptation activities. Ethiopia faces a huge financing gap to respond to climate change. Additionally, climate expenditure was mainly concentrated in the Ministry of Agriculture and the Ministry of Water, Irrigation, and Energy. Although there was an increase in climate-related expenditure by the Ministry of Health, the expenditure on climate is low. Ethiopia relies heavily on donor funds, yet these funds are off-budget and hard to track.

RECOMMENDATIONS

Based on climate and health systems synthesis, this document recommends the following actions to assist decision-makers with planning effective adaptation measures to address climate-related health risks:

- Integrate health climate **adaptation planning** at all administrative levels, which includes formalizing and resourcing the National Climate Change and Health Technical Working Group led by the Ministry of Health and enhance climate-related communications for government officials and the general public.
- Develop climate-related **educational and training materials** and implement training for healthcare workers that would allow them to understand the health impacts of climate change.
- Support **climate-health-related research** to develop surveillance of climate-sensitive diseases, climate-informed early warning systems, and response mechanisms and guide future vulnerability adaptation assessments.
- Improve **healthcare accessibility** to these facilities by enhancing the transportation network to ensure access to facilities during extreme weather events.
- Enhance the health system resilience via the development and implementation of **national building codes/permits**, which would consider sustainable energy (e.g., solarization of healthcare facilities) and water supplies, storm drains and sewers, and sanitation services.
- Develop **regulations** that support sustainable **healthcare waste management** and policies on key **environmental health services and determinants**; this could include establishing and maintaining a climate and environmental health database to support these regulations that would allow for multi-sectoral engagement and inform disease control and prevention programs ahead of potential extreme weather events.

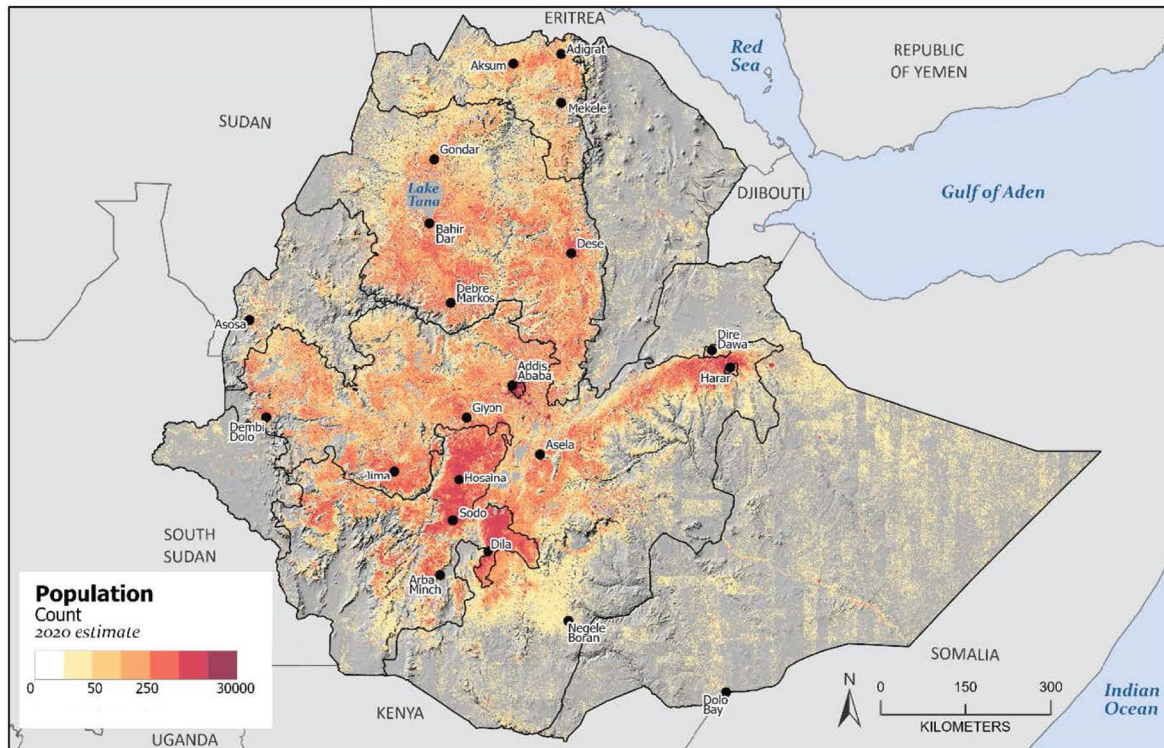
INTRODUCTION

COUNTRY CONTEXT

- 1. Ethiopia, located in the horn of Africa, is the second most populous country in Africa with total population estimated as roughly 110 million people.** Ethiopia's Human Development Index (HDI) value for 2019 was 0.485 [1], positioning the country in the low human development category (rank 173 out of 189). However, this figure doubled when compared to the 2000 HDI, 0.292. HDI of Ethiopia in 2018 was below the average of both the low human development group countries and countries in Sub-Saharan Africa, 0.513 and 0.547, respectively [1]. It is predominantly a young demographic, in which children below five years of age account for 14.6 percent of the population. Data is limited on educational attainment for the total population. Among the total urban population aged 10 years and above, 81.8 percent were found to be literate. The proportion of literate males are higher than that of the females, 89.2 percent versus 75.2 percent, respectively. Half of the literate attained elementary education (Grade 1-8) [2].
- 2. Ethiopia's population is growing rapidly with one of the fastest rates in the world at 3.02 percent per year.** At this rate, the population will reach 210 million by 2060, doubling the current population size [3]. This is similar to other projections which have suggested that the Ethiopian population is projected to reach 133.5 million in 2032, and 171.8 in 2050 [4]. Population density across the country varies substantially and depletion of natural resources might occur as the livelihood of most of the rural community is reliant on the natural environment. The central highlands from north to south have the highest population density, while the north-eastern, southern and south-eastern pastoral low land areas are less densely inhabited (Figure 1) [5].
- 3. Ethiopia's gross domestic product (GDP) grew by 6.1% in 2020 [6].** The annual GDP was US\$ 107.65 billion in 2021, with unemployment at 3.1 percent of total workforce [6]. Ethiopia is in 174th position among the poorest of the 196 countries according to their GDP per capita. People living in multi-dimensional poverty in Ethiopia is 58.5 percent [1]. Over 45 percent of Gross Domestic Product (GDP) and 80 percent of exports comes from agriculture, which also accounts for 83.4 percent of the labor force. The population is predominantly rural with nearly 80 percent living in rural areas, mainly based on subsistence agriculture [2].

FIGURE 1.

Population Density in Ethiopia, 2020



Source: Oak Ridge National Laboratory

4. Ethiopia faces significant climate-related challenges that will directly influence population health outcomes.

Coupled with human-induced health stressors, climate change exacerbates existing health burdens as well as creating new health risks. Changes in temperature and precipitation patterns affect the country and burden of a variety of climate-sensitive health risks while simultaneously impacting the functioning and capacity of Ethiopia's health system. Compounding these challenges, climate exacerbates health and economic inequalities that are not uniformly distributed, which can significantly affect population health risks. Challenges that increase Ethiopia's vulnerability to adverse health outcomes associated with climate change include the wide range of climate hazards that affect the country due to its diverse geography (e.g., floods and droughts),

a strong dependency on rainfed agriculture that is susceptible to regular climatic shocks, ongoing population growth, and chronic and widespread under-nutrition.

5. Ethiopia is committed to meeting the climate challenge through both adaptation and mitigation measures.

Ethiopia ratified the Paris Agreement in 2017, which aims to limit global mean temperature increase to well below 2°C compared to pre-industrial levels and has developed several policy frameworks that aim to reduce the country's vulnerability to climate change related impacts, including to human health outcomes. Adaptation is a high priority for the country due to the climate-related hazards that already pose significant risks. Section IV of this assessment highlights the key steps adopted by the government of Ethiopia to meet its climate change goals.

AIMS OF THIS ASSESSMENT AND CONCEPTUAL FRAMEWORK

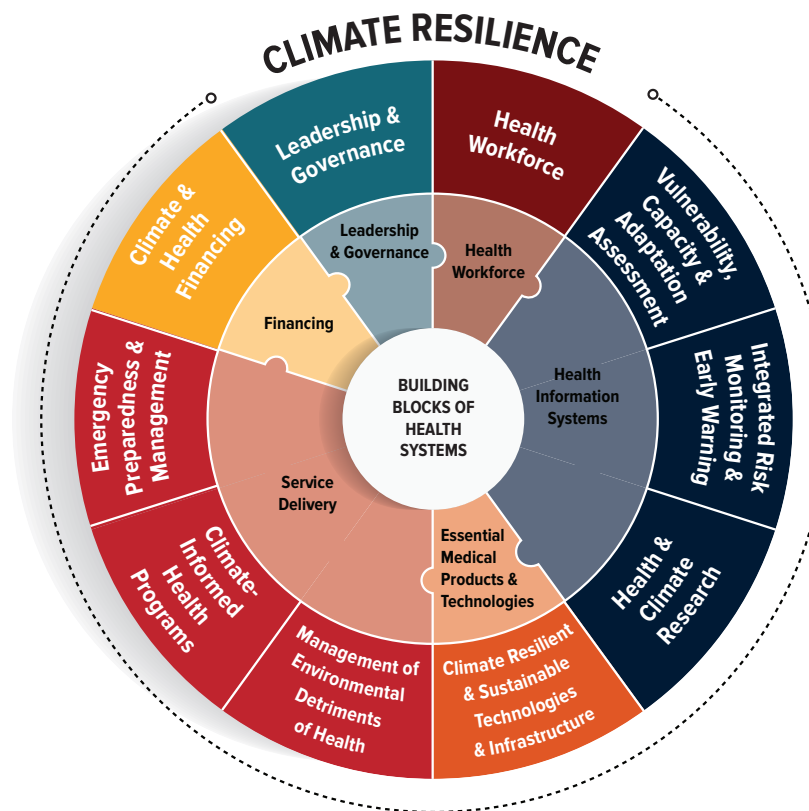
6. **The objective of this Climate and Health Vulnerability Assessment (CHVA) is to synthesize current research evidence and review relevant government documents to assist decision makers with planning effective adaptation measures to address climate-related health risks.** Where available, these measures are provided at a sub-national level to assist regional health planners. The recommendations of this CHVA are primarily aimed at Ethiopia's Ministry of Health, but also include other ministries whose actions can influence the health risks from climate, such as disaster risk management, agriculture, and natural resources and climate change.
7. **Adaptation priorities need to be accompanied by fundamental and urgent action to mitigate climate change.** It is important to stress how complex the climate challenge is and how hard it is to predict exactly how severe climate exposures facing populations will become. There are many factors that could slightly slow or significantly speed up rates of change including positive feedback effects and cascading climatological tipping points which are the most worrisome. For this reason, mitigating existing greenhouse gas emissions (GHGs) and developing and implementing measures to protect human health from the changing climate is of paramount importance.

8. **Investment in adaptation strategies to proactively address the effects of climate change on health outcomes is critical.** This assessment outlines climate risks to health, the adaptive capacities that are in place to deal with these risks, and recommendations to meet identified gaps. The primary focus of this assessment is, therefore, on climate adaptation and resilience measures. However, as the Intergovernmental Panel on Climate Change (IPCC's) Assessment Report Six (AR6) makes clear 'Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered' [7]. Mitigation alone is no longer a sufficient strategy regardless of the pace with which governments and communities around the world act. Adaptation is now as critical a part of climate action as mitigation. Therefore, this report focuses on adaptation measures, but where possible, also includes recommendations that reduce GHGs or facilitate decoupling of emissions from progress towards human health goals.
9. **The World Health Organization's (WHO) operational framework for building climate-resilient health systems [8] is adopted to analyze the adaptive capacity to adequately deal with current and future identified risks.** Following this framework (Figure 2) the adaptive capacity section of this CHVA is first structured around the six Health System Strengthening (HSS) building blocks. These

Mitigation alone is no longer a sufficient strategy regardless of the pace with which governments and communities around the world act. Adaptation is now as critical a part of climate action as mitigation.

FIGURE 2.

World Health Organization (WHO) operational framework for climate-resilient healthcare systems [8]



six categories encompass the assessment of capacities and gaps, now and into the future. The CHVA then moves on to consider the 10 components of health system climate resilience.

10. The CHVA follows a stepwise linear approach.

The first step characterizes the **climatology** in Ethiopia highlighting the observed and future climate exposures relevant to health. The second step examines **climate-related health risks** including identifying vulnerable populations most at risk. The final step assesses the **adaptive capacity of the health system** identifying gaps to manage current and future climate-related health risks. Together these steps inform a series of **recommendations**

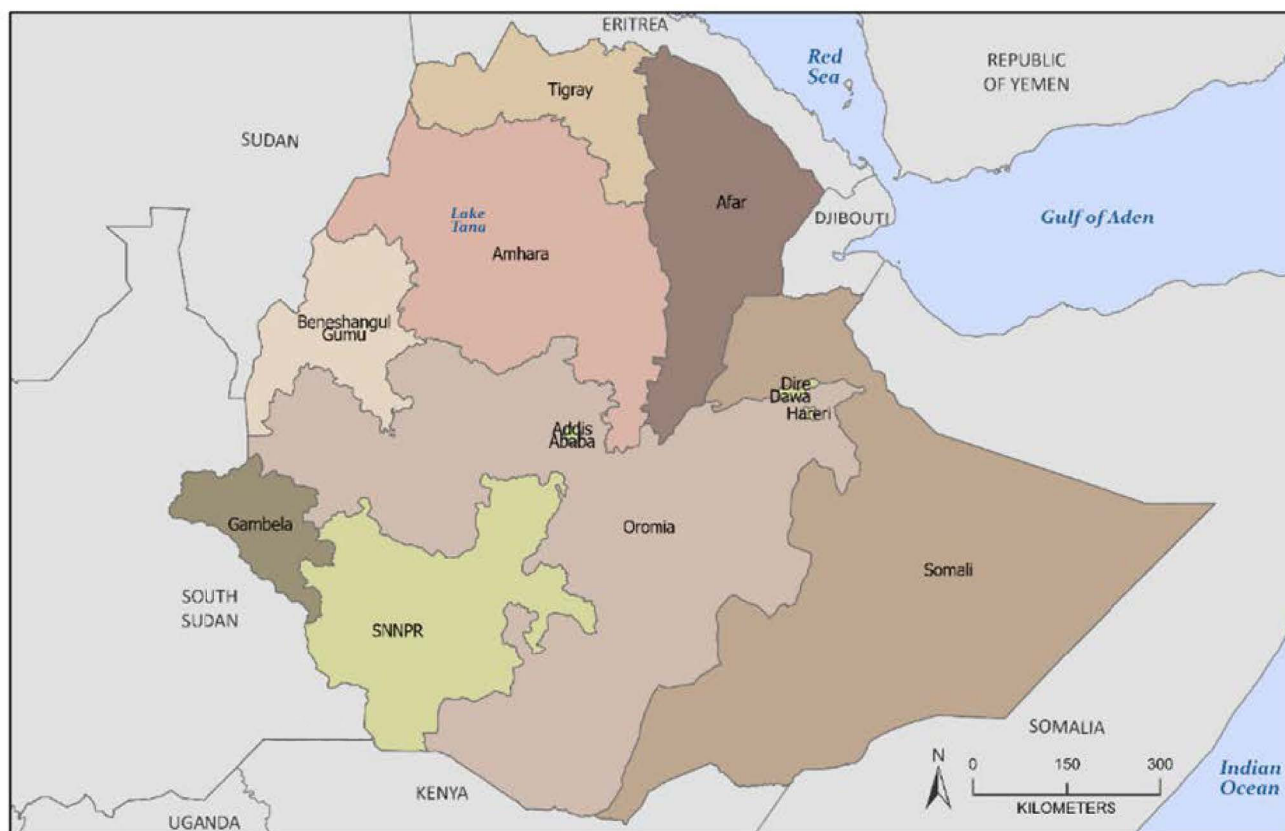
to reduce climate-related health vulnerability in Ethiopia. The CHVA is based on a review of the published literature, national statistics, and consultations with key counterparts in government and at the Ethiopian Public Health Institute, with individuals specializing in climate and health risks.

11. The CHVA incorporates sub-national consideration for health-related climate action.

Ethiopia's administration is classified into regional states that again sub-divide into zones and districts, locally called *Woreda* (Figure 3). *Woredas* are the implementing organ of the Government, and are themselves comprised of **Kebeles**, the smallest administrative unit.

FIGURE 3.

Administrative boundaries of Ethiopia



Source: World Bank Cartography Unit



CLIMATE CHANGE: OBSERVED TRENDS AND PROJECTIONS

- 1. This section describes observed climatic changes and projected climate trends, highlighting the priority climate-related hazards in relation to human health risks in Ethiopia.** Climate information is taken from the World Bank Group's Climate Change Knowledge Portal (CCKP) where historical, observed data is derived from the Climatic Research Unit, University of East Anglia (CRU). Climate data used in the World Bank Group's CCKP is derived from CMIP6, the Coupled Model Inter-comparison Project, Phase 6. The CMIP efforts are overseen by the [World Climate Research Program](#) and CMIP6 is the foundational data used to present global climate change projections presented in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). CMIP6 relies on the Shared Socioeconomic Pathways (SSPs), which represent possible societal development and policy scenarios for meeting designated radiative forcing (W/m²) by the end of the century. Scenarios are used to represent the climate response to different plausible future societal development storylines and associated contrasting emission pathways to outline how future emissions and land use changes translate into responses in the climate system. This assessment explores observed climate conditions for the latest climatology, 1991-2020 and projected climate conditions and changes under SSP3-7.0 for the near (2030s; 2020-2039) and medium term (2050s; 2040-2059).

ETHIOPIA'S GEOGRAPHY

- 2. Ethiopia is a land locked country located within 3.3°N-15°N and 33°E-48°E, in the Horn of Africa. It has a land mass of 1.14 million square kilometers [9].** The country has a diverse landscape affecting its climate, ranging from equatorial rainforest with high rainfall and humidity in the south and southwest, to the Afro-Alpine on the summits of the Simien and Bale Mountains, to desert-like conditions in the north-east, east and south-east lowlands.

Ethiopia is cleaved into eastern and western escarpments with high and uneven plateaus and peripheral lowlands by the Great African Rift Valley. The topography gradually slopes up from the lowland edges of Rift Valley to the eastern and western escarpments into the southern, central, western and northern mountains [10]. Along with wide plateaus, there are mountains which are typically 1,500-3,000 meters above sea-level, with some peaks over 3,500 meters. Overall, Ethiopia is considered

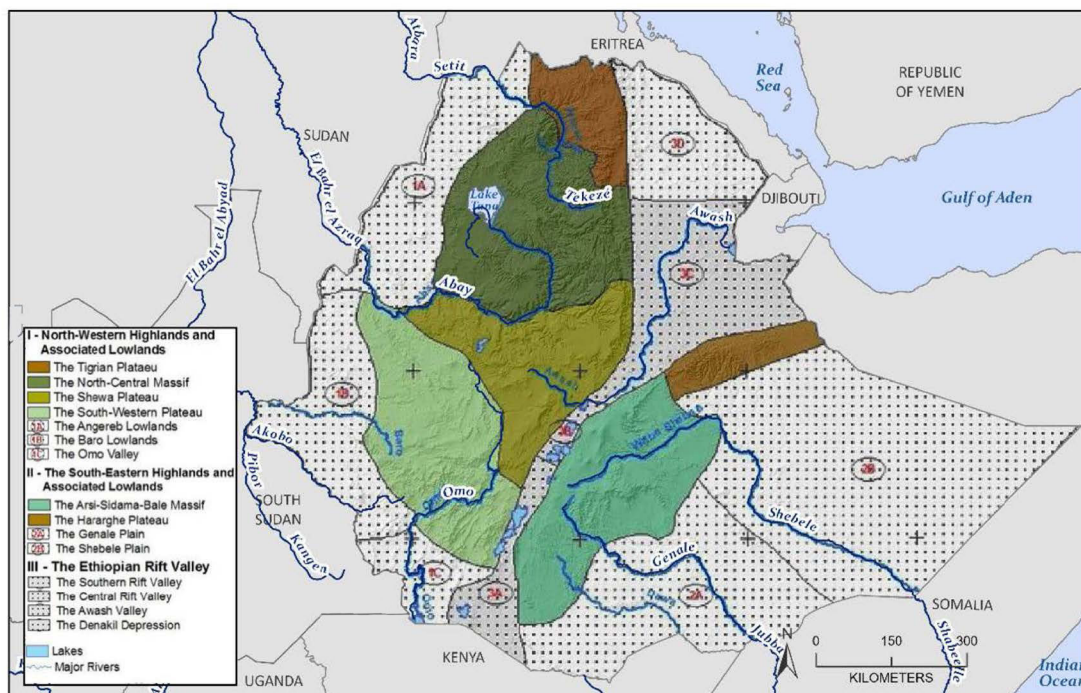
largely arid, but exhibits a high variability of precipitation. Ethiopia has three homogeneous geographic categories - (i) north-western highlands and associated lowlands, (ii) south-eastern highlands and associated lowlands, and (iii) the Ethiopian Rift Valley [10]. (Figure 4).

3. **Ethiopia's rivers originate in the highlands and flow outward in through an array of deep gorges.** Most notable of these is the Blue Nile, the country's largest river. In the northern half of the Great Rift Valley flows the Awash River, on which the government has built several dams to generate power and irrigate major commercial plantations. The Awash flows east and disappears into the saline lakes near the border with Djibouti. The Genale and Shebele rivers and their tributaries drain the southeast, and the Omo drains the southwest [11].

OBSERVED AND PROJECTED CLIMATOLOGY

4. **Ethiopia's climate is strongly influenced by its varied topography and the seasonal movement of the Intertropical Convergence Zone (ITCZ), which produces tropical, subtropical, and temperate regions, each featuring a range of precipitation conditions (Figure 4, also see Annex F on observed and projected temperature and precipitation changes by subnational unit).** The *Kolla* or hot zone describes areas <1500 meters in elevation, which align with the tropical zones classified by Sayre et al. as having mean annual temperatures of 24-34°C [149]. These areas include the arid east, the Denakil Depression, and the Blue Nile Valley, among other peripheral lowlands in the south and west [11]. The *Weina Dega* or temperate zone

FIGURE 4.
Physiographic regions of Ethiopia



Source: Woldemariam M (1972). An introductory geography of Ethiopia. 215 Pp. Addis Ababa.

encompasses parts of the northwest, central, and southeastern highlands with elevations 1500-2400 m, such as the capital Addis Ababa, Hareri, and most major cities in the highlands [11]. Sayre et al. distinguish between warm temperate zones with mean annual temperatures of 10-18°C and subtropical zones with mean temperatures of 18-24°C, which characterize many of Ethiopia's subnational units' mix of both temperate highlands and tropical lowlands.

5. **Ethiopia has three rainfall seasons – *Bega*, *Belg*, and *Kiremt* – that are characterized by different durations and intensities according to region and are also subject to high interannual variability.** Mean annual precipitation in Ethiopia can range from less than 450mm in Afar and Somali to more than 1,150mm in Beneshangul Gumu, SNNPR, and Addis Ababa. The primary rainy season, *Kiremt*, typically occurs from mid-June to mid-September and accounts for 50–80 percent of annual rainfall. Parts of central and northern Ethiopia (Addis Ababa, Amhara, Tigray, Afar, Dire Dawa, Hareri) experience a sporadic, secondary wet-season, *Belg*, which often has considerably less rainfall and occurs from February to May [12]. SNNPR, Somali, and Oromia receive their wettest or nearly wettest month during *Belg*. The cooler dry season, *Bega*, typically occurs from October to December, associated with a shift in high pressure over the Red Sea. Since the ITCZ drives much of the seasonal rainfall patterns in Ethiopia and inter-annual variability is often influenced by ENSO events, the onset and intensity of rainy seasons vary by region and year.

TEMPERATURE

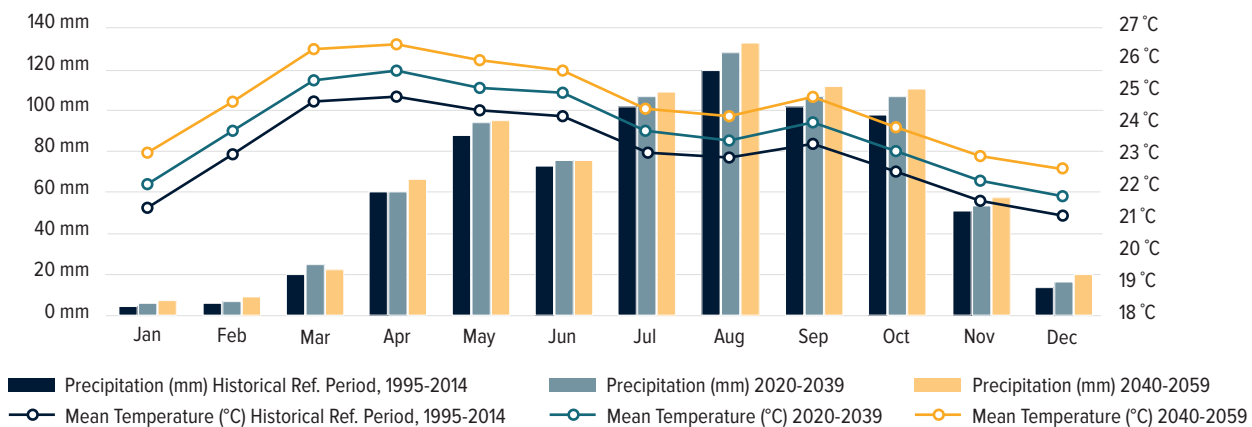
6. **Mean annual temperature in Ethiopia has increased by 1°C since 1960, an average rate of 0.25°C per decade, with the most notable increases observed from July through September [13].** The average number of “hot” nights (the hottest 10 percent of nights annually) increased by 37.5 percent between 1960 and 2003, while the average number of hot days per year increased by 20 percent [14]. At the sub-national level, higher rates of warming have been observed in the central regions and highland areas [15].
7. **Mean monthly temperatures in Ethiopia are projected to increase by 0.7°C by the 2030s, 1.5°C by the 2050s, and 3.1°C by end of the century, under a high emissions scenario (SSP3-7.0) when compared with the historic reference period (1995-2014) [13] (Figure 5).** This will result in corresponding increases in projected mean annual temperature of 24.8°C by the 2030s, 24.6°C by the 2050s, and 26.0°C by the end of the century with the highest temperatures likely to be seen in the eastern regions of Somali and Afar and the western region of Gambela. Moreover, annual temperature anomalies will increase across Ethiopia under emissions scenario SSP3-7.0 through the 2030s and 2050s, (+0.6°C to +1.5°C and +1.2°C to +2.6°C, respectively) (Figure 6). Seasonally, temperature increases will spike and be felt from June to January under high-emissions scenarios. Gambela is projected to experience the highest increases in daily max temperatures, particularly in March, April and May, with temperatures reaching 41.0°C by the 2030s and 42.1°C by the 2050s under emissions scenario SSP3-7.0.

8. The frequency of 'hot' days (TMax > 35°C) and tropical nights (Tmin > 20°C) will substantially increase in projected future climates in Ethiopia. Annual projections indicate that the number of 'hot' days for the whole country will increase from 69 by the 2030s to 87 by the 2050s (under SSP3-7.0), whereas tropical nights are projected to increase from 105

to 127 nationally, under the same timeframe and scenario, with higher increases in Afar, Somali, and Gambela regions (Table 1). The most rapid increases are expected in the July, August, and September season. Moreover, the increase in summer days (Tmax > 25°C) are expected to be pronounced with the whole of the country experiencing summer days for

FIGURE 5.

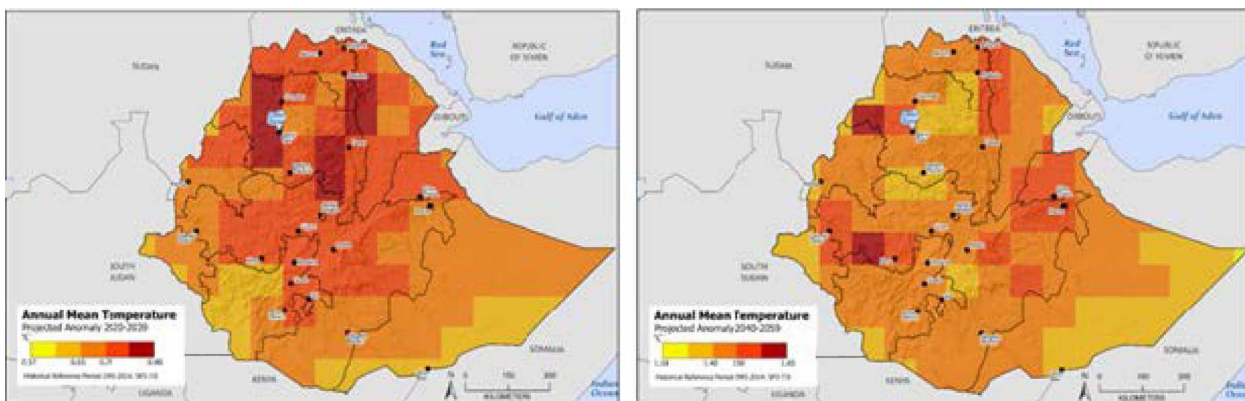
Observed and projected average monthly temperature and precipitation patterns in Ethiopia under SSP3-7.0



Source: World Bank Climate Change Knowledge Portal

FIGURE 6.

Projected temperature anomaly for 2020-2039 and 2040-2059 under SSP3-7.0



Source: World Bank Climate Change Knowledge Portal

TABLE 1.

Annual number of hot days (TMax > 35°C), tropical nights (Tmin > 20°C), and summer days (Tmax > 25°C) in the 2030s and 2050s under SSP3-7.0 in Ethiopia and key regions

HISTORICAL REFERENCE PERIOD		2030s	2050s
Number of Hot Days (TMax > 35°C)			
Ethiopia	55	69	87
Afar	89	104	124
Somali	96	126	161
Gambela	181	199	226
Number of Tropical Nights (Tmin > 20°C)			
Ethiopia	87	105	127
Afar	121	139	163
Somali	189	223	256
Gambela	251	280	306
Number of Summer Days (Tmax > 25°C)			
Ethiopia	307	317	328
Afar	341	348	352
Somali	360	362	363
Gambela	364	364	365

Source: World Bank Climate Change Knowledge Portal

nearly 90% of the year by the 2050s (Table 1). Dangers related to increasing heat index¹ is expected to be less pronounced in Ethiopia given low levels of atmospheric moisture, with the number of days with a heat index greater than 35°C ranging from 0 to 26 in Gambela annually by the 2050s.

PRECIPITATION

9. An overall decline in annual precipitation has been observed in Ethiopia over the last three to four decades, with significant year-to-year volatility (Figure 7) [13]. However, high inter-annual rainfall variability makes interpretation of long-term trends challenging and results in variations across regions and seasons

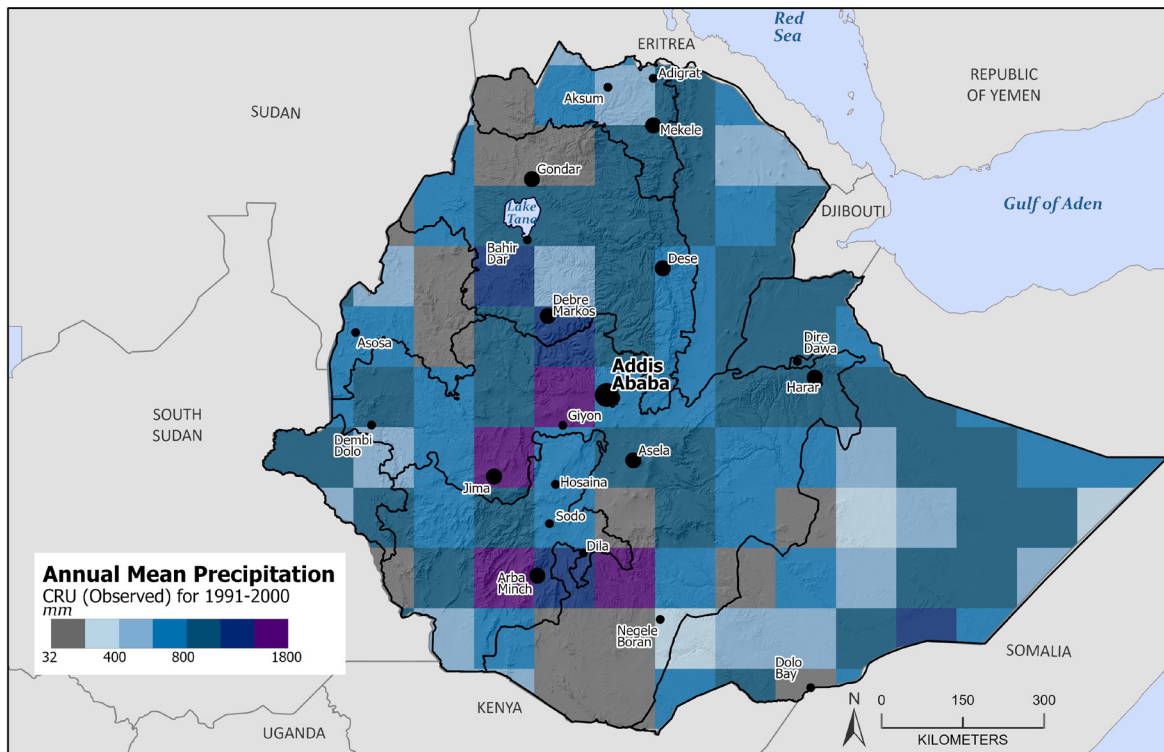
[16]. For example, historically the south-central region of the country has experienced a 20 percent decrease in rainfall since 1960, whereas the northeast and eastern regions only observed a decrease in rainfall during Belg, a secondary rainy season.

10. Future projections of precipitation under different climate change scenarios contain high degrees of uncertainty, due to the previously described high degree of inter-annual variability. For example, projected trends indicate continued declines in rainfall, as much as a 20 percent in spring and summer rainfall in southern and central regions in Ethiopia, whereas other areas are projected to experience increases in rainfall [13]. Under emissions scenario SSP3-7.0 the national average annual precipitation will increase by nearly 100mm by the 2050s when compared with the historical reference period. In Addis

¹ Heat Index is a measure of apparent temperature that includes the influence of atmospheric moisture. High temperatures with high moisture lead to high Heat Index. Heat Index gives insight into seasonal heat risks and changing seasonal heat risks over time.

FIGURE 7.

Annual mean precipitation, observed (1991-2020)



Source: World Bank Climate Change Knowledge Portal

Ababa, which sees the most rainfall, the level will increase from 1364mm under the historical reference period to 1580mm by the 2050s under SSP3-7.0. It is also projected that the proportion of heavy precipitation events will increase throughout the country, especially during the July to September and October to December rainfall periods [14]. Nevertheless, projected warming trends for the entire country are expected to exacerbate observed declines in rainfall, leading to increased water stress [13] (see section drought).

CLIMATE-RELATED HAZARDS

11. Ethiopia is vulnerable to several climate-related hazards, many of which have already demonstrated increases in frequency and intensity. The most pressing climate-related hazards are drought, flooding, landslides, and

extreme heat. The overall impacts of such events in Ethiopia will not merely be attributable to changing environmental conditions including changes to climatology described in the previous section, but are compounded by anthropogenic causes including rapid deforestation, urbanization, and inadequate building regulations and housing issues.

DROUGHT

12. Climate change is contributing to increases in the frequency and magnitude of droughts in Ethiopia, particularly in lowland areas, affecting the health and livelihoods of millions of people. On average, roughly 1.5 million people are affected by drought annually [17]. Although high degrees of inter-annual variability exist for precipitation trends across Ethiopia, the incidence of drought

has increased and the rainfall patterns from February to May have become increasingly less predictable in central and northern areas. Deficits in water availability are greatest in Tigray, Afar, and Somali regions. Moreover, increases in sea surface temperatures in the Indian Ocean influences the migration of the Intertropical Convergence Zone, which can further increase variability in the timing and duration of rainfall seasons, altering traditional rainfall patterns and causing more frequent drought. Water resources are also likely to be increasingly strained as precipitation is expected to increase in some parts of East Africa and warmer temperatures will accelerate the rate of evapotranspiration, thus reducing the benefits of increased rainfall [13].

13. The projected maximum number of consecutive dry days (in which the daily accumulated precipitation is less than 1 mm) is expected to vary by region and season in Ethiopia. For example, Somali is projected to see up to 81 consecutive dry days in December, January, February compared to 44 days in September, October, November, by the 2030s (SSP3-7.0) whereas the Gambela will experience between 75 to 11 days seasonally over the same period. Projected mean precipitation anomalies demonstrate

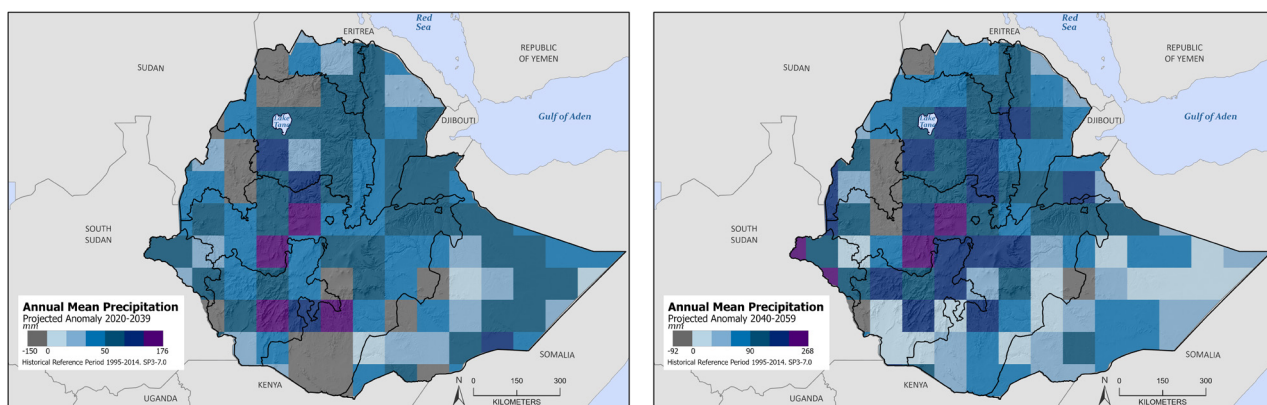
a similar variability across the country, with changes ranging from -14.1mm to +21.2mm by the 2030s and 16.8mm to +27.4mm by the 2050s under emissions scenario SSP3-7.0 (Figure 8). By mid-century under SSP3-7.0 scenario, the country as a whole will see a slight decrease in the annual projected number of consecutive dry days, 205 compared to 203 for the historical reference period. Nevertheless, droughts remain one of the key drivers of food insecurity for the country resulting in crop damage, loss of pasture and water sources, loss of animals, hunger, disease outbreaks, asset depletions, malnutrition and migration.

FLOODS

14. Flash floods and seasonal river floods are becoming more frequent and widespread in Ethiopia. Projected trends indicate that through the end of the century there is a likely 20 percent increase in extreme high rainfall events (20mm or more) increasing the risk of floods [13] [18]. On average, roughly 250,000 people are exposed to flooding risk annually [17]. Riverine areas in Ethiopia are at risk of seasonal flooding, especially during Kiremt season (June, July, August), including many lowland flood-prone areas that are adjacent to Awash, Wabi Shebele, Baro-Akobo, Omo-Gibe

FIGURE 8.

Projected precipitation anomaly for 2020-2039 and 2040-2059 under SSP3-7.0



Source: World Bank Climate Change Knowledge Portal

In terms of extremes, by mid-century Ethiopia is projected to experience 100-year average largest one-day and five-day precipitation events more frequently (future return periods of 51 and 54 years, respectively).

River and Abay Rivers. Additionally, flash floods are common in highland areas, such as those in the Awash River basin in the Rift Valley, as well as urban areas, particularly Addis Ababa [17].

- 15. The projected seasonal precipitation percent change varies by region, ranging between 5-24 percent in 2020-2039 and 9-40 percent in 2040-2059 with the highest increases occurring in Afar region.** Although Addis Ababa is projected to see the highest increases in the maximum number of consecutive wet days annually. Afar will experience the largest change in the number of days (+9 by mid-century under SSP3-7.0). Addis Ababa will also see the greatest number of days with precipitation > 20mm (nearly nine by the 2050s), whereas the largest changes in average largest one-day precipitation will occur Beneshangul Gumu (+10 by mid-century under SSP3-7.0). Hareri will have the highest anomaly for average largest five-day cumulative rainfall (+38 days by mid-century under SSP3-7.0) which presents a different flood risk where areas become saturated over a number of days. By mid-century, the national annual average largest five-day cumulative rainfall is projected to exceed 131mm. In terms of extremes, by mid-century Ethiopia is projected to experience 100-year average largest one-day and five-day precipitation events more frequently (future return periods of 51 and 54 years, respectively).

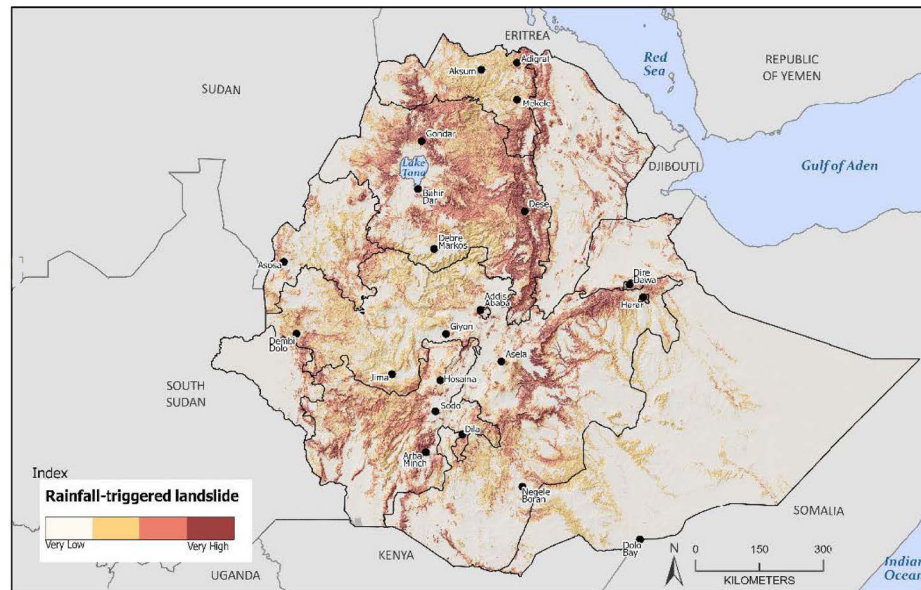
LANDSLIDES

- 16. Landslides are responsible for loss of life along with damage to infrastructure (including homes, transport, energy generation, and health facilities) in Ethiopia, and ongoing climate change will increase landslide risk.**

An average of approximately 1,000 people are affected by landslides annually in Ethiopia. The central areas of Ethiopia (Figure 9) contain the highest landslide risk, particularly along the eastern boarder of Tigray region and into the Amhara region. It is estimated that around one percent of the total land area of Ethiopia is classified as very high landslide hazards, with highland areas (which account for nearly half the country and a large proportion of the population) also highly susceptible to landslides [17]. Due to the link between landslides and heavy rainfall, the projected increases in average largest five-day precipitation events related to climate change, suggest the potential for future risks in the coming decades. Changes in rainfall and temperature may lead to more landslide events, with rainfall being a primary trigger, increasing drought followed by heavy precipitation events and changes in vegetation can affect the likelihood of these events. Development and land use policies impact landslide risk as well, with deforestation and unmanaged and unregulated planning of the built environment exacerbating landslides by weakening slope stability.

FIGURE 9.

Rainfall triggered landslide



Source: Global Facility for Disaster Reduction and Recovery (GFDRR)

EXTREME HEAT

17. Rising temperatures in Ethiopia are of increasing concern, including the increased frequency of extreme heat events [19].

Although the projected number of days with a heat index $>35^{\circ}\text{C}$ remain low until mid-century, under high-emissions scenarios increases are expected to begin in the 2080s, particularly in Gambela and Somali regions during March-May. Moreover, under SSP3-7.0 a sharp increase in hot days ($T_{\text{max}} > 35^{\circ}\text{C}$) with acceleration starting by 2050 and continuing until the end of the century [13]. Annually, Ethiopia is projected to experience an increase in the number of hot days ($T_{\text{max}} > 35^{\circ}\text{C}$) from 54 during the historical reference periods to 87 by the 2050s under SSP3-7.0. Under

the same time period and scenario, Afar, Somali, Gambela, and Beneshangul Gumu will experience the highest increases. For 'very hot' days ($T_{\text{max}} > 35^{\circ}\text{C}$) a similar pattern exists. The number of tropical nights ($T_{\text{min}} > 20^{\circ}\text{C}$) will also increase with climate change in Ethiopia, albeit with more dramatic increases. For example, by mid-century populations in Gambela region will see tropical nights for 80 percent of the year, compared to 68 percent for the historical reference period. The increase in tropical nights is important for human health, especially in areas that regularly do not experience high temperatures (e.g., highland areas), because it restricts the human body's ability to cool down.

Annually, Ethiopia is projected to experience an increase in the number of hot days ($T_{\text{max}} > 35^{\circ}\text{C}$) from 54 during the historical reference periods to 87 by the 2050s under SSP3-7.0.

SUMMARY OF CLIMATOLOGY

Temperature

- Historically, mean annual temperature in Ethiopia has increased by 1°C since 1960, including increases in both ‘hot’ days and nights, with the highest rates of warming observed in the central regions and highland areas.
- Under a high emissions scenario (SSP3-7.0) temperatures are projected to increase by 0.7°C by the 2030s, 1.5°C by the 2050s, with the highest temperatures likely to be seen in the eastern regions of Somali and Afar and the western region of Gambela

Precipitation

- Overall decline in annual precipitation has been observed in Ethiopia over the last three to four decades, with significant year-to-year volatility.
- Future projections of precipitation under different climate change scenarios contain high degrees of uncertainty, with slight increases in national average annual precipitation rates. However, continued warming trends will likely exacerbate seasonal and regional declines in rainfall.

Climate extremes

- **Drought:** Increases in drought risk are expected in Ethiopia, with declines in water availability greatest in Tigray, Afar, and Somali regions.
- **Floods:** Flash floods and seasonal river floods are significant risks in Ethiopia, with projected 100-year average largest one-day and five-day precipitation events projected to occur more frequently.
- **Landslides:** Climate change may increase landslide risk, with central areas of Ethiopia, particularly along the eastern boarder of Tigray region and into the Amhara region most vulnerable.
- **Extreme heat:** The frequency of ‘hot’ days (TMax > 35°C) and tropical nights (Tmin > 20°C) will substantially increase in projected future climates in Ethiopia, with Afar, Somali, Gambela, and Beneshangul Gumu likely to experience the highest increases.

CLIMATE-RELATED HEALTH RISKS

1. **Climate change influences human health outcomes and disease in multiple ways.** This section reviews evidence for the burden of current climate-related health risks in Ethiopia and projections of future risks of health outcomes due to climate change, based on the expected changes in a countries' climate under an RCP 8.5 (high GHG emissions) scenario. This scenario represents a 'realistic' worst-case scenario as the "worst-case" scenario, characterized as fossil-fuel intensive, that excludes any climate mitigation policies. It has been used as a likely outcome in the absence of mitigation actions. Health risks are presented according to prioritization and are examined according to historic, current and projected risk, where information is available. Risks to health system related to climate change are covered in Section IV - Adaptive Capacity.

2. **Risks to health outcomes related to climate change are not evenly distributed in the population with some groups at greater risk than others.** Climate change may exacerbate health inequalities, especially among certain vulnerable population groups, including the poor, rural populations, those living in informal urban settlements, women and young children, the elderly, those living with pre-existing conditions and disabilities, and displaced populations. Therefore, investment in adaptation and mitigation measures must carefully consider groups who would directly benefit from or may be disadvantaged by adopted measures.

3. **Neglected tropical diseases (NTDs) are also of high importance in Ethiopia and in some instances may be affected by climatic factors.** In particular, Visceral Leishmaniasis, trachoma and meningitis are the common ones, with over 4,500 cases reported yearly in endemic areas, and a propensity to spread because of climate change. These diseases tend to spread from hot (or *Kolla*) to adjacent mid-highland (or *Weina Dega*) zones [20], with the potential for re-emergence. Previous projections indicate more than one-thirds of Ethiopia's total land mass is at high and very high risk of visceral leishmaniasis endemicity [21], and above 3.2 million people live in areas at risk. Meningitis outbreaks also repeatedly occurred in Ethiopia. Although projections specific to meningitis prevalence in the future of Ethiopia's climate is absent, as dryness will prevail with the rising temperature and environmental changes it appears risk of meningitis outbreak is highly likely.

4. **Ethiopia's CHVA assesses six climate-related health risk categories.** These include risks to (a) nutrition and food security risks, (b) vector-borne disease, (c) water-borne and water-related disease, (d) heat-related

risks, (e) air quality, and (f) mental health. Risk categories were selected from literature review on climate and health risks to Ethiopia. Each category is assessed in terms of current and future risk, with considerations for both national and sub-national peculiarities, where possible. It is important to note that these risk categories represent only the most pressing climate-related health risks to the population of Ethiopia. Other climate-related health risks can include, but are not limited to, direct injuries and mortality associated with natural hazard events.

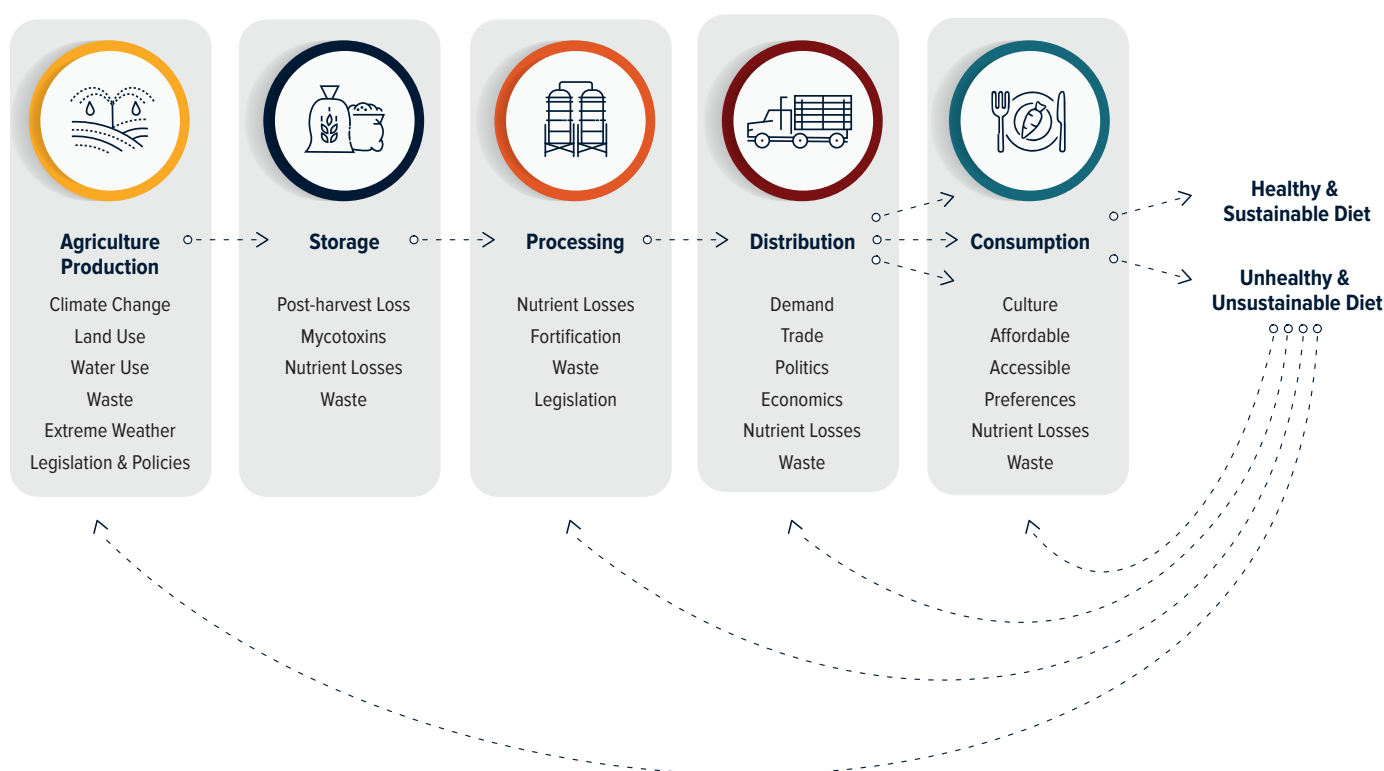
NUTRITION AND FOOD SECURITY RISKS

5. Weather and climate are foundational drivers of healthy and sustainable diets.

The mechanisms by which climate change affects nutrition via the food system are profound and include acute and chronic effects on agricultural production, storage, processing, distribution, and consumption (Figure 10). Nutritionally secure and stable diets depend on agricultural production, but also on the complex interactions of demand,

FIGURE 10.

Stages of the food system that drive healthy and sustainable diets [22]



Nutritionally secure and stable diets depend on agricultural production, but also on the complex interactions of demand, economics, legislation, conflict, food waste, nutrient losses, food safety, and access.

economics, legislation, conflict, food waste, nutrient losses, food safety, and access [22]. Climate variability is already contributing to increases in global hunger and malnutrition [23]. While a comprehensive analysis of climate change's impact on the food system is beyond the scope of this assessment, this CHVA examines climate and nutrition linkages through a food security lens in Ethiopia as it relates to weather and climate impacts on agricultural productivity. Agricultural productivity is a key determinant of food availability and is affected by weather and climate in a multitude of ways, from short term shocks (e.g., natural disasters), to longer term changes in agro-ecological conditions that can drastically reduce yields or re-define spatio-temporal patterns of crop suitability.

6. **Rain-fed agriculture is a major climate-sensitive concern in Ethiopia, particularly with changes in rainfall pattern and intensity as a result of increasing drought and flood events.** Crops are sensitive to unpredictable climate hazards such as floods and pests. The impact is most significant in communities which rely on subsistence and/or rain-fed farming and livestock production, which is relevant to approximately 70-80 percent of the population in Ethiopia [24]. Although the country will see a slight decrease in the annual projected number of consecutive dry days, droughts will remain one of the key drivers of food insecurity, causing crop damage, loss of pasture and water sources, loss of animals, hunger, disease outbreaks, asset depletions, malnutrition and migration.
7. **High morbidity and mortality are immediate consequences of undernutrition and results in a predisposition to infections, particularly those of the gastrointestinal and respiratory systems [25].** Globally, undernutrition caused

an estimated 45% of all deaths in under five years of age, with most of those being in low-income countries [26], a figure that was also identified in 2011 data when aggregating fetal growth restriction, stunting, wasting, and deficiencies of vitamin A and zinc along with suboptimum breastfeeding [27]. Children with Severe Acute Malnutrition (SAM) face a risk of morbidity and mortality nine-to-eleven times greater than their healthy counterparts [28]. The burden of SAM in children under five is projected to increase in Sub-Saharan Africa from 8.1 million cases in 2014 to potentially 9.0 million cases by 2030 [29].

8. **In Ethiopia, although there has been progress to improve nutritional outcomes, especially in children under five years of age, under-nutrition continues to be a priority health risk.** Ethiopia has one of the highest levels of food insecurity in the world, in which more than 35 percent of its total population is chronically undernourished [30] and an estimated 20.4 million people require food support [31]. Between 2000 and 2016, under-5 mortality declined from 166 deaths per 1,000 live births to 67 deaths per 1,000 live births, representing a 60 percent decrease, in part due to an enhanced focus on undernutrition. Nationally, 38 percent of children under age 5 are stunted (short for their age), 10 percent are wasted (thin for their height), 24 percent are underweight (thin for their age), and 1 percent are overweight (heavy for their height). Amhara, Benishangul-Gumuz, Affar, and Dire Dawa are the regions that are most affected by child stunting (41-46 percent), whereas wasting imposes the heaviest burden in Somali, Affar, and Gambela, with rates of 23, 18, and 14 percent, respectively (Table 2). This continues to affect childhood mortality, with large variations across regions in Ethiopia. For example, under-5 mortality ranges from a

TABLE 2.

Under 5 Child stunting, wasting and mortality rates by sub-national units [32]

REGIONAL STATES/CITY ADMINISTRATIONS	CHILD STUNTING (%)	CHILD WASTING (%)	CHILD MORTALITY (PER 1000 LIVE BIRTHS)
Addis Ababa	15	4	39
Diredawa	40	10	93
Benshangul-Gumuz	43	12	98
Harari	32	11	72
Afar	41	18	125
Amhara	46	10	85
Oromia	37	11	79
Gambella	24	14	88
Southern Nations, Nationalities, Peoples (SNNP)	39	6	88
Tigray	39	11	59
Somali	27	24	94

low of 39 deaths per 1,000 live births in Addis Ababa to a high of 125 deaths per 1,000 live births in Afar.

weather shocks such as drought, with large areas of the country not being suitable for cultivation [34].

9. Droughts, soil erosion, reduced water supply and increased crop damage worsen food insecurity. Increased extreme rainfall triggers soil erosion and reduces soil fertility, aggravated by prolonged drought periods. Soil erosion is also worsened by deforestation rates in Ethiopia. Moreover, droughts have increased in frequency, duration, and intensity which has and will likely continue to impact Ethiopia's rain-fed agriculture system, potentially leading to reduced crop yields, especially for smallholder farmers which represent most of the rural population and produce more than 90 percent of total agricultural output [33]. The five major crop cereals in Ethiopia are teff, wheat, maize, sorghum and barley, which account for roughly three-quarters of the total cultivated land. However, yields are considered to be low by international comparisons, mainly due to

10. Food security is a significant growing risk due to the acute shocks and chronic changes of climate projections. For example, three categories of the main staple food producers from within Ethiopia are already impacted by the changing climate, further increasing food insecurity. Many southern and south-eastern pastoral areas experienced lower-than-normal pasture and water availability, which will cause significant food and income loss as a result. Additionally, climatic shocks as well as compounding factors such as conflict, desert locust invasions, and the COVID-19 pandemic continue to drive up levels of food and nutrition insecurity and prices of staple foods in Ethiopia. These conditions all drove further declines in living conditions and deteriorating food security and increased levels of malnutrition affecting an estimated 18 million people [35].

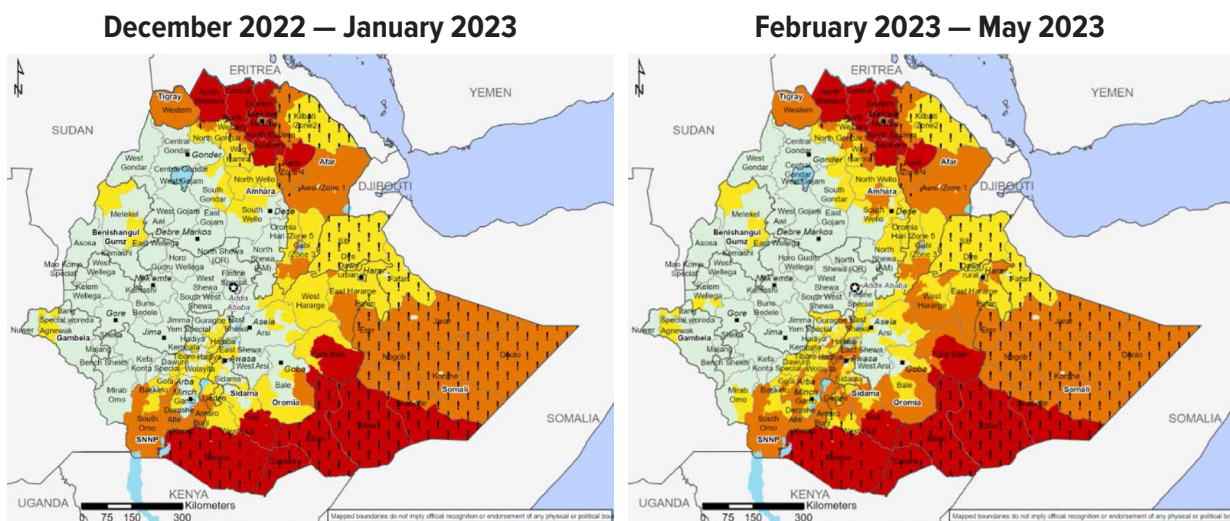
11. Ethiopia is currently facing five consecutive drought seasons (below-average rainy seasons) in the south and southeast pastoral regions, and households are expected to face increased food insecurity. Nearly 2.3 million people in the Somali region face difficulty accessing food. Acute malnutrition levels are categorized as Critical in the Amhara Region. (see Figure 11 with recent data and projections for Tigray conflict-affected areas).

12. Considering the observed overall decline in annual precipitation and increases in the frequency and intensity of droughts, as well as the potential shifts in rainfall patterns under climate change, Ethiopia may continue to face important consequences related to the replenishment of soil moisture, the availability of water resources and therefore on

food security for both the 2030s and the 2050s. Water scarcity in Ethiopia is pivotal for agriculture and livestock. Overall, there is a high level of uncertainty regarding projections of precipitation under different climate scenarios in Ethiopia, with key indicators such as maximum number of dry days (in which the daily accumulated precipitation is less than 1 mm) is expected to vary by region and season. However, the shifts in precipitation and threat of continued drought conditions coupled with a limited water management infrastructure, as well as a lack of development in the agricultural sector, will potentially increase the vulnerability to food insecurity. In particular, areas that already experience a high burden of undernutrition, such as Tigray, Afar, and Somali regions will also face the greatest deficits in water availability.

FIGURE 11.

Ethiopia: Acute Food Insecurity projected outcomes, December 2022-January 2023 and February-May 2023 [36]



IPC v3.1 Acute Food Insecurity Phase

1: Minimal 2: Stressed 3: Crisis 4: Emergency 5: Famine

! Would likely be at least one phase worse without current or programmed humanitarian assistance.

FEWS NET classification is IPC-compatible. IPC-compatible analysis follows key IPC protocols but does not necessarily reflect the consensus of national food security partners.

VECTOR-BORNE DISEASE RISKS

13. Weather and climate are critical drivers of spatio-temporal vector-borne disease (VBD) distribution and transmission dynamics.

At large scales, climate variability causes vector and host ranges to change, shifting disease distribution, seasonality, and/or facilitating emergence or re-emergence of VBDs [37]. At local scales, vector abundance is a product of microclimates, availability of larval sites, shade for resting, sources of blood meals and nectar, and predator density [38].

14. Climate is a critical driver of vector borne disease distribution and transmission dynamics.

Climate variability causes vector and host ranges to expand or contract, shifting disease distribution, seasonality, and/or facilitating emergence or re-emergence of vector-borne diseases. Investigating species distribution and seasonality of vectors is valuable to understanding plausible vector-borne diseases distributions and planning efficient, spatially targeted methods of control. This assessment focuses on malaria considering its importance for morbidity and mortality in Ethiopia; there are more than 40 species of *Anopheles*, however *Anopheles arabiensis* is the principal malaria vector (others that transmit malaria in Ethiopia are *A. funestus*, *A. phronesis*, and *A. nili*, and there is recent documentation of *A. stephensi* in eastern Ethiopia [39]). The other main vector borne diseases in Ethiopia are dengue fever (*Aedes aegypti*), chikungunya (primarily *Aedes aegypti* and *Aedes albopictus*), and Yellow Fever (*Aedes aegypti*). Since 2013, above 12,000 dengue fever cases documented due to repeated outbreaks were reported in eastern Ethiopia [40], with peak high malaria prevalence being observed between September to November [41]. Because of the overlapping feature of epidemiology of dengue

fever and malaria, vectors of both diseases breed in small water pools in discarded utensils adjacent to households and entail transmission as documented and took actions to abrupt the outbreaks [42]. Similarly, Chikungunya outbreaks are repeatedly documented in eastern Ethiopia [43]. Figure 12 from the Ethiopia MoH provides a spatial analysis of malaria incidence for the year 2020, stratified by district [110].

15. Malaria transmission risk in Somali region will decline in the 2030s and 2050s due to ongoing climate change, however hot spots will remain, particularly in Hadiya, Metekel, and South Gonder districts (Figure 13).

Spatial models were constructed to demonstrate the plausible distributions of *Anopheles arabiensis* mosquitoes according to environmental suitability. Here, suitable areas are defined as those that facilitate the development of malaria mosquitoes through the production and persistence of oviposition sites and where temperatures do not exceed or fall below thermal tolerances for the species. It can be assumed that where suitability for malaria vector species is greatest so too is malaria transmission risk in the absence of interventions. For further information on modelling methodology and inputs see Annex E. Suitability for malaria vectors through mid-century will largely remain unchanged throughout the country as projected temperature increases will not exceed the thermal tolerance of malaria vector species. Only in Somali region during the 2030s and 2050s, will temperature increase limit vector survival (Figure 13). Overall, the projected decline in suitable area for malaria is estimated to reduce the number of people vulnerable, however suitability for some regions will remain high through the 2050s (Table 3). For example, areas that are populated and

FIGURE 12.

Malaria Risk Map, 2020 [110]

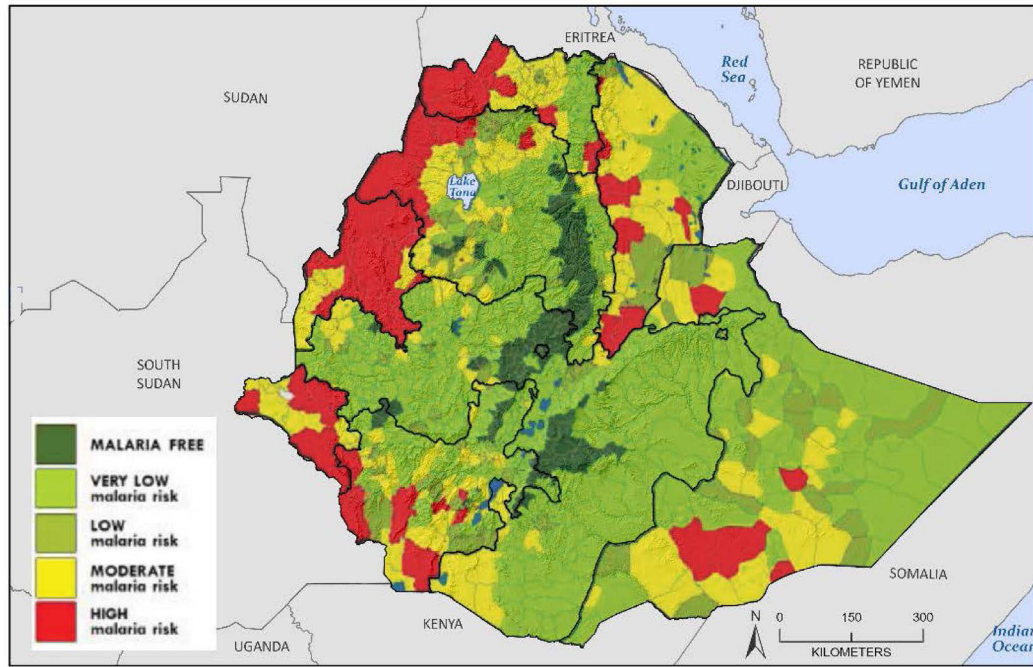
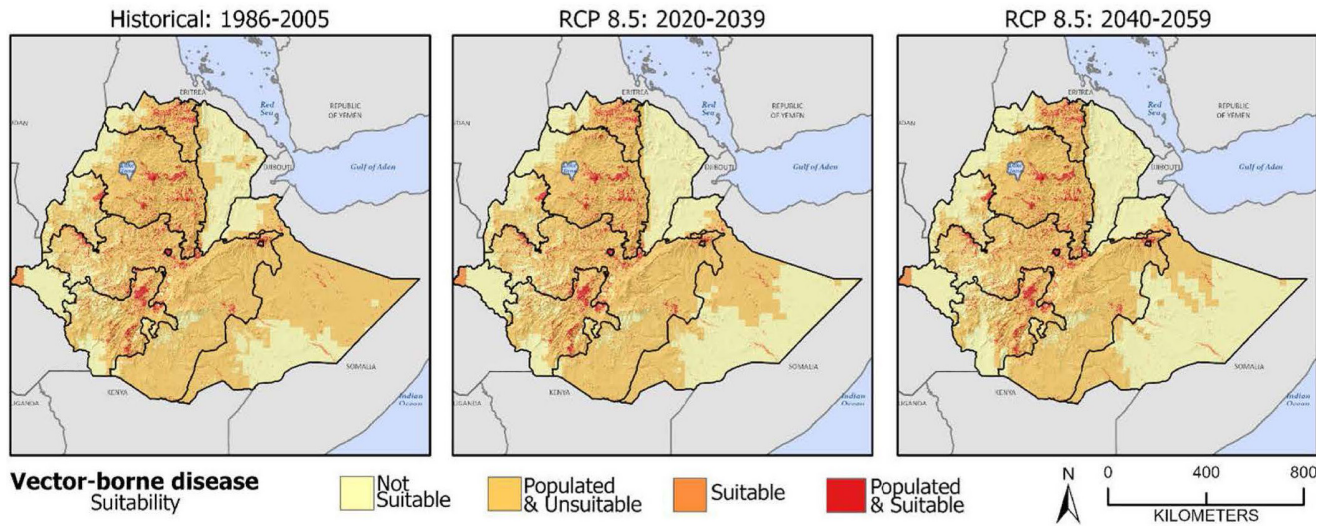


FIGURE 13.

Comparison of suitable area for malaria vector species in Ethiopia under RCP 8.5, across three epochs: 1986-2005 (historical baseline), 2020-2039, and 2040-2059



Sources: Temperature (NASA, NEX-GDDP) Land Cover (Copernicus Global Land Service, Proba-V-C3), Water Resources (European Commission's Joint Research Centre, GSW1_0), Flow Accumulation (World Wide Fund for Nature, HydroSHEDS), Population (European Commission's Joint Research Centre, GHSL/P2016/POP_GPW_GLOBE_V

TABLE 3.

Percent suitable habitat area, by region, for malaria vector species in Ethiopia under RCP 8.5 through mid-century

Region	POPULATED, SUITABLE			OVERALL SUITABILITY			VULNERABLE POPULATION		
	Historic	2030s	2050s	Historic	2030s	2050s	Historic	2030s	2050s
Addis Ababa	85.2	85.2	85.2	99.3	99.3	99.3	3,511,125	3,511,125	3,511,125
Afar	0.5	0.4	0.2	25.1	11.8	8.2	672,763	396,715	328,389
Amhara	8.8	8.8	8.8	86.5	85.5	83.8	21,710,871	21,682,958	21,621,787
Beneshangul Gumu	2.8	2.8	2.6	56.2	50.8	37.5	987,467	963,352	888,200
Dire Dawa	13.4	12.4	13.2	100.0	97.7	96.4	454,061	454,061	453,453
Gambela	0.1	0.1	0.0	5.2	3.3	1.7	161,801	99,505	89,089
Hareri	33.1	33.1	33.1	100.0	100.0	100.0	245,872	245,872	245,872
Oromia	4.8	4.8	4.8	88.0	87.3	85.1	36,436,944	36,429,879	36,310,886
SNNPR	9.9	9.9	9.7	72.4	71.0	65.3	19,735,888	19,733,884	19,567,096
Somali	1.0	0.7	0.5	71.6	41.8	26.4	4,398,716	3,356,939	2,714,751
Tigray	10.5	10.3	10.2	78.2	70.3	65.4	5,313,756	5,202,492	5,164,616
TOTAL	93,629,269	92,076,787	90,895,269						

Sources: Temperature (NASA, NEX-GDDP) Land Cover (Copernicus Global Land Service, Proba-V-C3), Water Resources (European Commission's Joint Research Centre, GSW1_0), Flow Accumulation (World Wide Fund for Nature, HydroSHEDS), Population (European Commission's Joint Research Centre, GHSL/P2016/POP_GPW_GLOBE_V

suitable for malaria in Addis Ababa will continue to be roughly 85 percent resulting in approximately 3.5 million people vulnerable.

16. In Ethiopia, the influences of climate variability on malaria cases over time is well documented. Temperature and precipitation have been highlighted as important drivers of malaria epidemics, but their effects on malaria vary depending on local climate and geography [44] [45] [46] [47]. Overall, evidence has shown temperature is a more important driver in cooler highland regions, whereas precipitation is more important in drier areas. Although occurrence of endemic malaria is known to be limited to below 2000 meters above sea level, malaria cases were documented in highland-fringe areas beyond the altitude threshold during non-epidemic periods [48] [49] [50]. In addition, highland areas have seen a corresponding increase in the altitude at which malaria transmission is possible, exposing non-immune populations in new highland areas to risk of the disease [51].

Thus, approximately, there are an additional 6.5 million non-immune people in malaria risk areas. Evidence from the Sixth Assessment Report from the Intergovernmental Panel on Climate Change on the observed impacts and projected risks for malaria state that higher temperatures and shifting patterns of rainfall influence the distribution and incidence of malaria in sub-Saharan Africa with high confidence. Further there is evidence that of Increasing incidence of infection with *P. falciparum* with higher temperatures, particularly in Ethiopia. These relationships have led multiple researchers to propose applying climate-driven models for malaria early warning in Ethiopia [52] [53] [54].

17. Drought frequently drives water storage near households, putting *Aedes* breeding sites near humans. There was a re-emergence of Yellow Fever outbreaks during 2012, 2014 and 2018 in southern Ethiopia [55]. Moreover, during the 2000s, more frequent outbreaks of mosquito-borne diseases were recorded, which

was likely influenced by warming temperatures [56]. By the 2030s and 2050s, rainfall patterns and drought conditions will vary by region and season, however slight increases in the number of consecutive dry days are projected in Somali region, included roughly 44 dry days projected between the months of September-October, which are historically considered high malaria transmission months in Ethiopia [57].

WATER-BORNE AND WATER-RELATED DISEASES

18. In Ethiopia, diarrheal disease causes 12.8 percent of disability-adjusted life years (DALYs) among children under 5 years, mainly due to Salmonella and Shigella bacteria, and causes 8.6 percent of total DALYs for all ages [58]. They are caused by contamination of food, water, and bacteria in the environment. Climate change is increasing the magnitude of diarrheal diseases, with rising temperatures speeding up the life cycle and survival of pathogens and vectors [59]. Increases in rainfall as well as average temperatures play a major role in the transmission of diseases [60], influencing the proliferation, transport and dissemination of infectious agents, particularly through water and sanitation systems [61]. Households with unimproved water and sanitation facilities are most at risk of increases in diarrheal diseases, with 77 percent of the variation in the occurrence of diarrhoea being identified as being due to climatic differences in Sub-Saharan countries [62].

19. Common types of flooding in Ethiopia include riverine and flash, with groundwater and sewer-flooding also presenting hazards to human health. Inundation of agricultural land, villages, towns, and cities contaminates fresh water with human and animal sewage,

agricultural and other pollutants, as well as increased sediment loads in rivers - all affecting water quality. Bacterial pathogens attach to leafy crops under flood conditions, as well as in drought conditions [63]. Flies and other pests proliferate in flood waters, risking food contamination. The flooding also results in the geo-spatial expansion of breeding sites for vector-borne diseases, such as malaria, chikungunya and dengue transmitted through mosquitoes, which are explored in the vector-borne diseases section.

20. The 9 percent of deaths attributed to diarrhea diseases in Ethiopia [58] are an inevitable outcome of the poor water, sanitation, and hygiene infrastructure. Out of all children under five deaths, 13 percent are due to diarrheal diseases [58], such as cholera. Cholera is an acute diarrheal illness caused by infection of intestine with *Vibrio cholerae*, usually serogroup O1. In Ethiopia, it is estimated that about 70 million people are at risk of cholera. Of those, an estimated 275,221 cases and 10,458 deaths occur annually, representing an incidence rate of 4 cases per 1000 population [64]. The East Africa sub-region is projected to be the worst impacted by cholera, particularly during and after El Niño events [65]. It is estimated that 20,000-30,000 additional cholera deaths attributed to climate change in children below 15 years old [66].

21. Spread of enteric diseases can occur through direct use of the contaminated water for swimming, bathing, and drinking, through the contamination of food that is farmed or washed using contaminated water sources, or through person-to-person transmission. Projected increases in warm temperatures, shifting patterns of rainfall, and an increase in heavy precipitation events throughout Ethiopia are ideal for the rapid prolifera-

tion and persistence of pathogens, making the management and sustained control of outbreaks challenging. For example, Addis Ababa, which already experiences the most precipitation in the country, will see increases in rainfall through 2050 under high-emissions climate scenarios. Furthermore, the water and sanitation systems in Ethiopia have not received sufficient investment, leaving the population vulnerable to the transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, and typhoid. In low-income countries, changes in climate are expected to influence diarrhea rates [67], however the extent will vary depending on climate change scenarios and local factors [68]. Increased frequency of floods in Ethiopia is expected to exacerbate challenges with water pollution and subsequently will increase the risks of diarrheal diseases [69]. Although country-level projection of climate attributable diarrheal disease are unavailable, with projected climate change in the African region, an extra 48,000 deaths will occur in children aged below 15 years, mainly due to diarrheal diseases and 33,000 deaths by 2030 and 2050, respectively [66].

22. Climate change projections reveal a significant positive trend in temperatures, which are associated with increased episodes of diarrheal diseases [68]. More intense droughts are also associated with reduced water quality and disease outbreaks. The lack of fresh rain during droughts prevents the opportunity to flush out stagnant waters. The water quality deteriorates as sources become over-used, and the risk of outbreaks of disease spreading person-to-person increases, even away from the direct source of contamination. Warmer waters will contribute to increases in toxic algae blooms in fresh waters, and associated cases of food poisoning from affected aquatic foods, resulting in outbreaks.

HEAT RELATED MORTALITY AND MORBIDITY

23. The health risks of heat are wide ranging, including effects on mortality, heat-related injuries, mental health and well-being. Several factors influence mortality and morbidity related to extreme heat events with the magnitude of impacts related to the timing, duration, and intensity of the temperature event, levels of acclimatization (an individual's adaptive response to a hot environment), the built environment (e.g., urban heat island effect), the adaptive capacity of the affected populations, and resilience of infrastructure and institutions, among others [70]. Health effects caused by heat include the direct effect of heat stress, as well as heat rash, cramps, exhaustion, and dehydration and the acute exacerbation of pre-existing conditions including respiratory and cardiovascular diseases, with further risks of detrimental interactions for those on medications. Longer term mental health risks are also an important effect to consider. In addition to the impacts on individuals, the whole population exposure that occurs with an extreme heat event can lead to significant increases in hospitalizations putting strain on health systems [71].

24. Both increases in average seasonal temperatures and an increase in the frequency and intensity of heatwave events are projected to increase the health risks globally in a changing climate [66] [72]. There is no specific data on the impacts of heat on health in Ethiopia, the potential threat of elevated mortality risk still exists. Gambella and Afar regions have the highest average temperature in which institutional working adjustments have been recommended during peak season/ months (e.g., July, August, September). Further, in Ethiopia, from the climate change

projections described in Section II, Afar, Somali, and Gambela regions are likely to experience increases in the number of hot days (T_{Max} > 35°C) and tropical nights (>20°C) by 2050 under a high emissions scenario. This would expose roughly 13.3 million people to potentially life-threatening temperatures and will have implications on the health of those populations, particularly vulnerable groups such as pregnant women, children under five years of age, people over 65 years. Moreover, projected increases in summer days (T_{max} > 25°C) are expected to be pronounced with the whole of the country.

25. Extreme heat also presents a growing occupational health risk in Ethiopia. Physical work capacity can reduce when high temperatures and humidity exist several months each year, with some global assessments calculating annual loss of healthy work hours three-fold (from 3 percent to 18 percent) by 2100 [73]. Overall, there is a lack of reporting of heat related injuries, illnesses, and deaths amongst occupations in Ethiopia [74]. However, studies from other countries indicate that workers in agriculture and construction are at a particularly high risk of occupational heat stress [75]. Climate-based indices can be used to quantify workdays lost to extreme heat, reflecting recommended heat strain thresholds [75].

AIR QUALITY

26. The changing climate itself can influence other sources of air pollution with global mortality driven by the fossil fuel component of PM_{2.5} estimated as 10.2 million per year [76]. Changes in wind patterns and strength lead to increased fine particulate matter, such as atmospheric dust, desertification in some regions also promoting dust formation, and increasing risks of wildfire with heat and

droughts, resulting in severe health impacts from widespread smoke inhalation. High temperatures also interact with air quality, affecting levels of ozone, pollutants, and aeroallergens, which in turn can result in acute exacerbations of chronic respiratory and cardiovascular conditions [77]. For example, extreme heat and high humidity trigger asthma symptoms; and cold weather, by increasing cold exposure, will increase overall respiratory infections in individuals with underlying chronic obstructive pulmonary disease (COPD) [78]. Moreover, the changes in wind patterns and increased desertification themselves increase the long-range transport of air pollutants. Under certain atmospheric circulation conditions, the transport of pollutants, including aerosols, carbon monoxide, ozone, desert dust, mold spores, and pesticides, may occur over large distances and over timescales typically of 4-6 days, which can lead to adverse health impacts [79]. Other contributors to poor air quality in Ethiopia include power generation, diesel generators, and waste burning, all of which themselves contribute as a positive feedback mechanism to climate change impacts.

27. In Ethiopia, air pollution is the second highest risk factor for driving morbidity and mortality [80]. Specifically, it is estimated that air pollution in Ethiopia is responsible for 41 percent of lung cancer deaths; 47 percent of chronic obstructive pulmonary disease deaths; 25 percent of Ischaemic Heart Disease deaths; 19 percent of Diabetes deaths; and 17 percent of Stroke deaths [81], as well as other outcomes such as exacerbations of asthma and the advancement of dementia. A report by the Ministry of Health found that 1.2 million cases of acute upper respiratory infections (5 percent), as well as a further 5 percent of pneumonia cases (7 percent of total hospital admissions) may be linked

to air pollution (data from 2010/11) [82], with pneumonia rates highest amongst children under 5 years, accounting for 23 percent of their hospital admissions and 13 percent of their mortality [82]. Air pollution affects pregnant women, the developing fetus, or both, in ways analogous to tobacco smoking, which is a well-known risk factor for low birth weight and preterm birth. Other vulnerable groups are children under 5 years old, and the elderly through damage and inflammation in the respiratory and cardio-vascular systems in particular.

28. In Ethiopia, the World Bank Group estimated that the mortality rate caused by ambient and household air pollution was 144.4 per 100,000 population (data from 2016), this compared to 169.73 regionally, and 92.43 globally [83] [84]. In 2017, 7,540 deaths were attributed to exposure to outdoor PM_{2.5}, with a further 32,800 deaths attributed to Household Air Pollution, and 533 to ozone [81]. In total that is approximately 41,000 deaths, making it the 3rd leading risk factor for premature death, accounting for nearly 8 percent of all-cause mortality in 2017 [81].

29. The State of Global Air research group estimate that the entire Ethiopian population lives in areas with PM_{2.5} concentrations above the 2021 WHO Air Quality Guidelines [85] for healthy air of 5 µg/m³. They estimated that in 2017 the population weighted average PM_{2.5} concentration was 39 µg/m. There has been a trend of improvement, and in 2021 another group estimated the PM_{2.5} concentration at 20.1 µg/m [82]. However, smog areas of high pollution remain — available data indicates that Addis Ababa is the most polluted city, with the dry months of January and February having the concentrations of

up to 100 µg/m³ in the urban areas, with 40 µg/m (twice the average for the country, and 8x the WHO guidelines) in suburban area at the same time of the year [82].

MENTAL HEALTH AND WELLBEING

30. The association between climate change-related events and mental health can be direct or indirect, short-term, and long-term.

Acute events (such as a flood) in the short term can precipitate a psychopathological pattern similar to experiencing traumatic stress. Whereas exposure to extreme or prolonged weather-related impacts may result in delayed mental impacts, such as symptoms of post-traumatic stress in the future, or psychological impacts on younger generations. For example, mental health impacts in children can be manifested as behavioural disorders. In 2011 neuropsychiatric disorders were estimated by the WHO to account for 5.8 percent of the disease burden [86], while a paper published in the same year reported the mental disorders burden to be 18 percent in adults and 15 percent for children [87]. Diagnostic capacity in the country is minimal, perhaps explaining the discrepancies in the published data, and lack of recent sources. Nonetheless, the impact of climate change and climate extreme events on mental health and well-being is mediated by individual and community resilience. Even globally, the research on the effects of mental health outcomes related to climate change lags behind research related to physical health, and the assessment presents challenges due to the diversity in cultural issues and norms.

31. To assess mental health in the context of climate change, the full spectrum from mental illnesses to psychological and social wellbeing, or 'psychosocial health', is considered.

This allows for the incorporation of consider-

2 µg/m³=micrograms per meter cubed, ie one millionth of a gram

ations of wellbeing and resilience [88]. This is particularly relevant in Ethiopia, where there is a background strain on the resilience of the population due to food and income insecurity, long-term climate and conflict stresses, as well as limited opportunities for psychological or psychiatric assessment and diagnoses to inform an analysis. The concept of mental health and wellbeing can thus be framed as a spectrum of ‘psycho-social health’. This embodies the diverse psychological and social strains of climate change impacts — such as housing, water and income insecurities, as well as living in physically uncomfortable drought or humid conditions.

32. Extreme weather events, such as floods, can result in direct trauma, anxiety, and depression through personal injury, or death and injury of a close relative, damage or loss of property and important community services infrastructure, as well as disruption to livelihood. Intense negative emotions such as terror, anger, and shock are recognized as acute responses to natural disasters. These extreme events can also result in long-lasting psychological distress [89] [90].

33. Mental disorders such as depression, anxiety, and post-traumatic stress are related to increasing climate events. Extreme weather events such as floods and droughts, are becoming more frequent and intense in Ethiopia, potentially leading to increased risk of elevated rates of mental disorders. Although there is a lack of information on mental health disorders’ incidence and prevalence in Ethiopia, global figures show that 14 percent of the burden of disease is attributed to mental health illnesses [91]. Moreover, research shows that psychopathologies attributed to extreme weather events increases by 17 percent, impacting about 30-40 percent of

the population affected by natural disasters. Research suggests that this can persist up to two years after the event [92]. The destruction of landscape, such as through severe flash flooding, in itself diminishes the sense of belonging and comfort that people derive from their connectedness to the land [93].

34. Extreme heat also has an impact on mental health and well-being [94] [95]. High temperature can aggravate mental health symptoms, increase the risk of suicide [95], and conflict [96]. More generally, research has shown that hot nights are associated with insomnia [97], with consequences that included susceptibility for disease and chronic illness [98] [99] psychological and cognitive functioning [100] [101] [102]. Research in other countries has projected levels of heat-related excess mortality for mental disorders [103]. The trends between increasing temperatures and associated mental disorder has also been found in regard to self-harm and suicide rates. Some findings suggest that suicide rates increased by 0.7 percent and 3.1 percent, respectively, for a 1°C increase in monthly average temperature [104]. There are two likely mechanisms for this: First, direct physiological effects on the brain are hypothesized to influence emotional control, aggression, and violent behaviour. This direct mechanism appears to be driving increases in suicide rates on hot days in wealthy locations like the United States [105]. Second, high temperatures generate negative economic shocks, particularly in agriculturally dependent communities, which is critical for the subsistence farming population in Ethiopia [106]. These economic losses have been shown to translate into increased suicide risk [107].

35. There are many factors that influence mental health and wellbeing, and the nature of

resilience is not fully understood. For example, there is the opportunity for post-traumatic growth (PTG) following a climate change-related extreme weather event, as opposed the trauma being inevitable. The PTG term is described by Tedeschi and Calhoun (1995) as:

“significant beneficial changes in cognitive and emotional life beyond levels of adaptation, psychological functioning, or life awareness that occur in the aftermath of psychological traumas that challenge previously existing assumptions about self, others, and the future.” [108]

TABLE 4.
Summary of the Climate Change Risks on Health Outcomes

	CURRENT RISK	PROJECTED RISK
Nutrition and Food Security 	- Ethiopia suffers from food insecurity which has resulted in high levels of malnutrition. - Malnutrition is consistently the highest contributor to total DALYs over the 2009-2019 period, across all ages. - Nearly 33 million people are suffering from chronic undernourishment and food insecurity.	- In the absence of adaptation, climate change is predicted to increase the duration of droughts, and increase the frequency of flooding, resulting in a reduction in crop yield, aggravating food insecurity and increasing malnutrition. - Areas that already experience a high burden of undernutrition, such as Tigray, Afar, and Somali regions will also face the greatest deficits in water availability.
Vector-borne Diseases 	- In Ethiopia, there is a risk that the vectors for malaria have the opportunity to increase their spatial and temporal distribution, particularly in highland areas. - Evidence has shown temperature is a more important driver of malaria in cooler highland regions, whereas precipitation is more important in drier areas. - Outbreaks of Dengue Fever (eastern regions), Chikungunya (eastern regions) and Yellow Fever (southwestern regions) have also been recorded.	- All of these diseases could spread as changes in precipitation and population internal settlements provide increased habitats for breeding and opportunities for the respective mosquito species to flourish. - Areas that are projected to experience increases in drought conditions, such as Somali, may be at additional risk of vector-borne diseases.
Waterborne and Water-related Diseases 	- Waterborne and water related diseases occur throughout Ethiopia in response to inadequate water and sanitation systems, intense precipitation, drought conditions, and specific water contaminants. - Droughts of longer duration have been linked to reduced availability of fresh water, a deterioration in water quality, with stagnation and disease outbreaks.	Projected increases in warm temperatures, shifting patterns of rainfall, and an increase in heavy precipitation events throughout Ethiopia will likely influence the expanded ecosystem opportunities, the growth and transmission rates, as well as the persistence and virulence, of pathogens.

	CURRENT RISK	PROJECTED RISK
Heat-related Morbidity and Mortality 	- Heat-related morbidity and mortality data is still lacking in Ethiopia. - Exposure to extreme heat may be high, especially in urban areas, with occupational health risk from heat a major concern.	Afar, Somali, and Gambela regions are likely to experience increases in the number of hot days (TMax > 35°C) and tropical nights (>20°C) by 2050 under a high emissions scenario.
Air Quality and Respiratory Health 	- The burden of disease due to poor air quality is the second highest contributor to DALYs across all ages in Ethiopia. - The mortality rate caused by ambient and household air pollution in Ethiopia was 144.4 per 100,000 population in 2016, with the whole of the population currently living in areas with PM2.5 concentrations above WHO guidelines.	- It is challenging to project air quality health risks related to climate change due to the complex between air quality and climate change. - Increasing temperatures can interact with air quality affecting levels of ozone, pollutants, and aeroallergens, which in turn can result in acute and chronic adverse health outcomes. - Highly populated areas, such as Addis Ababa will likely be at risk of high air pollution rates, particularly during dry months
Mental Health and Well-being 	Information on mental health disorders' incidence and prevalence in Ethiopia is lacking, including associations with climate change, particularly extreme weather events.	Increases in extreme weather events, such as floods and droughts, increase the incidence of mental health and well-being concerns.



ADAPTIVE CAPACITY OF THE HEALTH SYSTEM

HEALTH SYSTEM OVERVIEW

1. **The Ethiopian health system has three-tier system including primary, secondary, and tertiary levels (Figure 14).** The latter is comprised of general and specialized hospitals, and the coverage of each extends to larger portions of the population. The district health office and regional health bureau are accountable to manage, coordinate and distribute supplies as well as render skill transfer. However, the Ministry of Health at the federal level is responsible for policy formulation and acts on critical matters of high-level concern, such as declaring epidemics.

FIGURE 14.

Ethiopia Health Tier System [109]

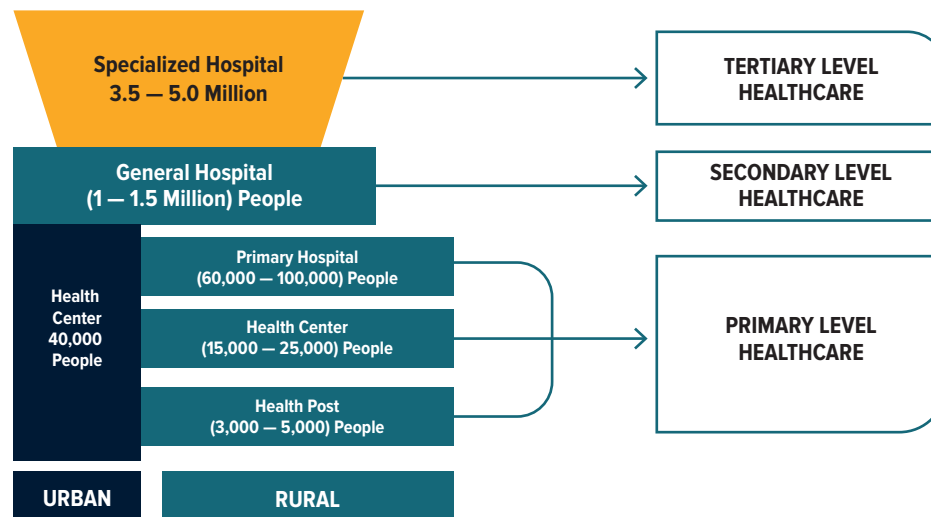
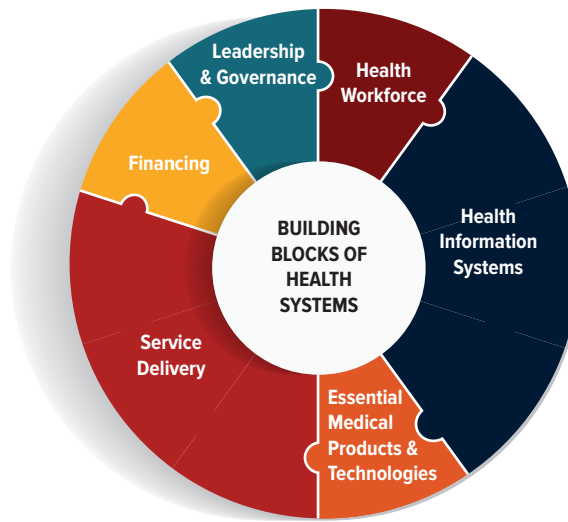


FIGURE 15.

WHO Health System Building Blocks [8]



2. **Woreda (or district) transformation has been the main scheme of enhancing the health sector.** This scheme began in 2015/16 as part of the first health sector transformation plan (HSTP-I). Several woreda transformation related reforms have been implemented, including the Ethiopian primary health care alliance for quality (EPAQ), Woreda management standards, and community scorecards. Performance of the Woreda health indicators is measured through demographic and health surveys - the DHS reports, demonstrating significant progress of Ethiopia's health system [110].
3. **The emergence of COVID-19 pandemic has brought with it a focus on health and health systems, specifically the capacity to manage emerging public health risks.** Climate change, like COVID-19, has the potential to disrupt and overwhelm health systems, including healthcare facilities and healthcare staff. The COVID-19 situation is ever-evolving in Ethiopia with cases continuing to be documented (as of June 2022), contributing to additional strains on the health system as well as additional economic uncertainties.

4. **The extent to which the health system in Ethiopia is prepared for and has the capacity to manage changes in hazards, exposure, and susceptibility, will determine their resilience in coming decades.** In this assessment, Ethiopia's adaptive capacity³ to prevent and manage climate-related health risks is examined according to the WHO's six health system building blocks, as shown in Figure 15 (see also the Annex A for a summarized *Adaptive Capacity and Climate Change-Related Health Risks Gap Analysis* and Annex C for an *Adaptive Capacity Rapid Assessment*, which inform this section). It should be noted that several factors outside the scope of the health sector can also drive reductions in adaptive capacity to manage the health risks of climate change in Ethiopia's institutions and people. These include the country's economic challenges, changing

3 Adaptive capacity is defined by the IPCC as, 'the ability of a system to adjust to climate change, moderate potential damages, take advantage of opportunities, and cope with the consequences' (IPCC AR5). The related term, resilience, is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. People and communities with strong adaptive capacity have greater resilience. This assessment makes use of the term adaptation and adaptive capacity to encompass both terms.

demographic patterns, and slowly improving social conditions. Promotion of equity as a cross-cutting theme for enhancing the adaptive capacity and resilience to the health risks of climate change is also critical. Adaptive capacity is likely to be greater when access to resources within a community, nation, or the world is equitably distributed.

LEADERSHIP AND GOVERNANCE

- 5. The Government of Ethiopia is acutely aware of the potential negative impacts of climate change.** As a result, the Government has been actively developing policies and plans to support mitigation and adaptation actions, as well as signing onto international and regional initiatives. Ethiopia submitted its updated Nationally Determined Contributions (NDC) in 2021, which updates the Intended Nationally Determined Contributions (INDC) completed in 2015 and outlines the country's climate change and mitigation and adaptation commitments [111]. Health is highlighted as a priority area, with six adaptation interventions described (second in number only to agriculture and climate service/disaster risks reduction). The interventions focus primarily on vector-borne diseases (malaria), water-borne diseases (cholera), and ensuring healthcare facilities are adequately resourced with safe water and sanitation and reliable electricity.
- 6. Under the National Framework of Climate Resilient Health Sector (2014) and National Health Adaptation Plan to Climate Change (2018-2020) a National Climate Change and Health Technical Working Group (TWG) was established to lead climate change and health adaptation activities.** The TWG uses existing health sector institutional arrangements from national to community and household level, as well as includes members from relevant MoH

directorates, line ministries, and development partners. The development of an updated Health National Adaptation Plan (HNAP) will aim to strengthen the TWG through the establishment of a MoH and Climate Change Directorate supported Steering Committee for National Climate Change and Health Adaptation.

- 7. The Climate Resilient Green Economy (CRGE) strategy (developed in 2010) focuses on reducing GHGs emission and using renewable energy resources as major source of energy for the country.** Ethiopia has also social protection policy which deals prevention, protection, transformation and promotion including post recovering of disasters victims through establishing community based social security fund. Through this fund, victims of flooding, fire, drought, landslide and other disasters as well as aged and disabled people will get support to recover from. The CRGE is also integrated into the Second Growth and Transformation Plan (GTP II) (the national development plan). GTP II (2016-2020) has mainstreamed CRGE to implement its four pillars: modernization of agriculture, industrialization, transformation and foreign trade development.
- 8. Ethiopia's National Adaptation Plan (NAP-Eth) was submitted for endorsement by the central government in 2017.** This plan embraces climate change adaptation through the integration with national development policy frameworks, such as Climate Resilient Green Economy (CRGE) strategy, the second Growth and Transformation Plan (GTP II), and sectoral climate resilience strategies and regional and municipal adaptation plans. Other relevant policies and strategies for climate change and health adaptation are Environmental Policy of Ethiopia, Agriculture

and Rural Development Policy and Strategy, Water Resources Management Policy, Health Sector Development Policy and Program, National Policy on Disaster Prevention and Preparedness, National Policy on Biodiversity Conservation and Research, Science and Technology Policy, Population Policy and National Agricultural Research Policy and Strategy.

9. At the sub-national level health-focused climate change adaptation planning is limited.

In Addis Ababa, there are some initiatives underway concentrated on the implementation of electric public transit systems and reducing air pollution.

10. The evolution of the climate change and health policy landscape in Ethiopia from 1994 is summarized in Figure 16 (see also Table 5 for a snapshot assessment of climate change and health policies and plans).

FIGURE 16.

Timeline of Ethiopia's Climate Change Policies [111]

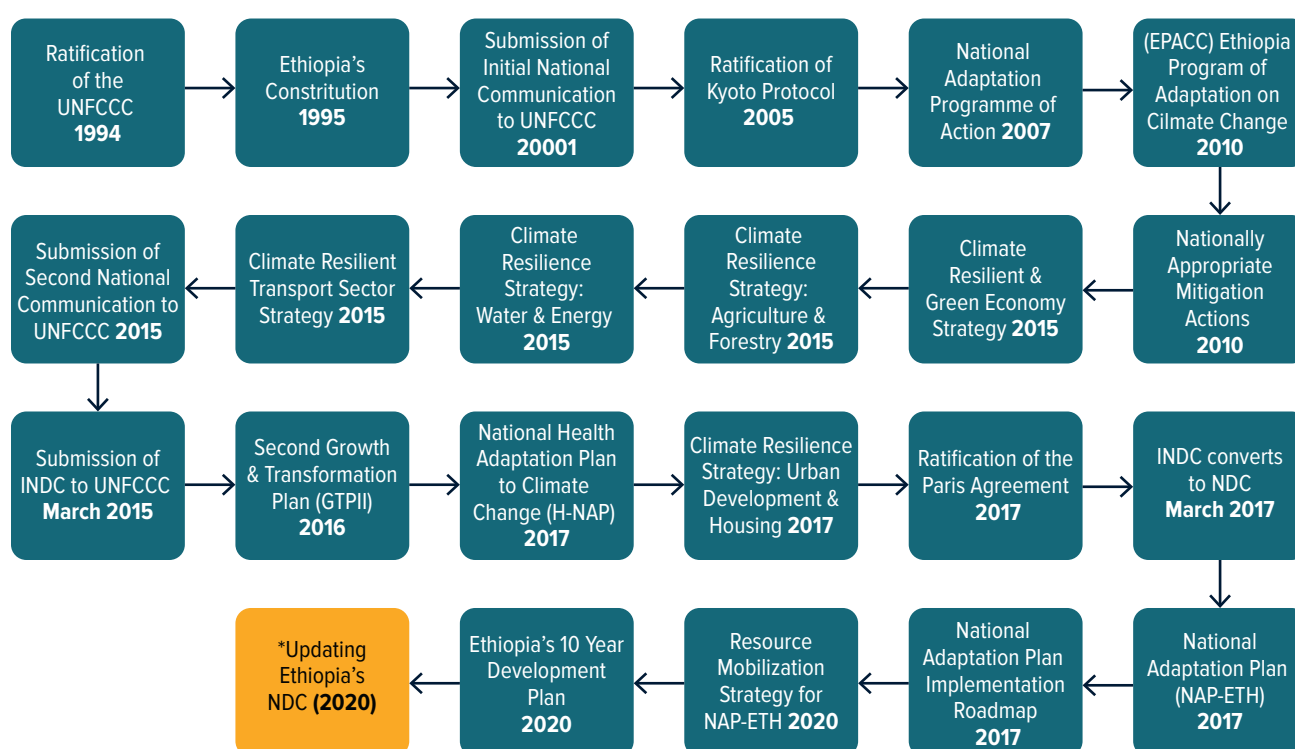


TABLE 5.

Assessment of key climate change and health related policies

DATE	POLICY OR PLAN	RELEVANCE FOR CLIMATE CHANGE AND HEALTH	CLIMATE CHANGE AND HEALTH RISKS
National (Climate Change and Health)			
Under-development	Health National Adaptation Plan II	Will guide operation of the strategic approaches for climate change and health adaptation.	Vector-borne diseases, water-borne diseases, malnutrition, heat stress, respiratory disease.
2018-2020	National Health Adaptation Plan to Climate Change	Serves as implementation guidance and link to the Health Sector Transformation Plan for building climate resilience in the health sector.	Vector-borne diseases, water-borne diseases, malnutrition, heat stress, respiratory disease.
2014	National Framework of Climate Resilient Health Sector	Serves as policy guidance and provide road map for the realization of Health National Adaptation Plan.	Vector-borne diseases, water-borne diseases, malnutrition, heat stress, respiratory disease.
National (Climate Change)			
2021	Updated Nationally Determined Contributions (NDC)	Outlines health as a priority section for adaptation.	Vector-borne diseases, water-borne diseases, climate-related impacts on healthcare facilities.
2017	National Adaptation Plan (NAP-Eth)	A framework and process for initiating the NAP, including identification of priority sectors, which include health.	Vector-borne diseases, water-borne diseases, malnutrition, flooding and displacement.
2016	Growth and Transformation Plan (GTP II)	Provides a national vision for becoming a low middle-income country by 2025, which includes aspects of strengthening the health sector	None specified.
2015	Intended Nationally Determined Contributions (INDC)	Provides initial targets for climate change mitigation and adaptation goals, with impacts on human health briefly mentioned.	None specified.
2015	2nd National Communication to the UNFCCC	Vulnerabilities, impacts, and adaptation assessment conducted for health sector.	Vector-borne diseases, water-borne diseases, malnutrition, heat stress, respiratory disease, risks related to extreme weather events.
2011	Climate Resilient Green Economy (CRGE) strategy	Follows a sectoral approach to create a green economy to meet developmental goals, with health included as a sub-technical committee.	Focused primarily on the health co-benefits of climate change mitigation policies.
National (Health)			
2020-2025	Health Sector Transformation Plan II	Climate change mentioned as a threat to the health sector	Focused on building climate resilience, particularly for WaSH systems
2015-2020	Health Sector Transformation Plan	Climate change as a threat to human health is highlighted prominently.	Focused primarily on building climate resilience in health sector and prevention infectious disease outbreaks.

HEALTH WORKFORCE

- 11. Decentralization of the health system has improved management and overall capacity of the health workforce in Ethiopia; however, it still lacks enough medical doctors and nurses to achieve WHO guidelines.** Ethiopia

faces numerous health workforce challenges, including urban-rural maldistribution, lack of proper skill mix, low quality of education, poor absorption capacity, rural retentions issues, international out-migration, and insufficient and irregular salary payments [112]. Simultaneously, climate change impacts the health workforce through mechanisms related to changes in the frequency and intensity of extreme weather events that may affect a facility or workers' ability to reach the facility, as well as altered patterns of climate-sensitive diseases, of which health professionals may not be able to respond to in a timely manner [113].

- 12. Health workforce in Ethiopia is below the WHO minimum threshold to achieve universal health coverage, 44.5 per 10,000 [114].** In 2020, the country had an estimated

1.06 medical doctors and 7.84 nurses and midwives per 10,000 population. In total, there are an estimated total of 12,174 registered doctors and 90,179 nurses and midwives [115]. Despite having a shortage of medical doctors and nurses, the country has expanded its workforce by increasing the number of Community Health Workers (42,630 by 2020 [115]) and Health Extension Workers (19,927 by 2019 [116]). Regarding mental health, there are no reports on the number of psychiatrists, psychologists, or nurses with mental health training [115]. On the other hand, the Health Extension Program, added more than 42,000 health extension workers since its creation in 2003, however, it is not clear what is the role and training of the extension workers.

- 13. There are limitations in the health workforce, both in professional expertise and distribution, as well as an overarching lack of information on the awareness of climate change and health risks among health workers.** The health workforce, particularly

doctors, are more concentrated in urban areas, mostly due to lack of basic services in rural or remote areas (water, road, electricity, education). By 2010 it was reported that 83 percent of doctors were located in urban areas [117]. Addis Ababa, for example, has a doctor density of 2.9 per 10,000 [116]. On the other hand, nurses and midwives are better distributed throughout the country, having an adequate ratio of nurses per 10,000 population in most of the regions. There is an uneven distribution of the health workforce across provinces, with most highly skilled professionals stationed in urban areas. There is no data on the quantity or level of expertise on climate-related health risks in the health workforce [117].

- 14. Labor conditions for health workers curtail health workforce capacity.** Current salaries

of health workers are low and lack adequate labor conditions, especially in rural areas where roads, communications, electricity and other basic services are limited or lacking. Poor working conditions have triggered the out-migration of skilled health workers (especially among medical doctors). Decentralization of the health system has increased autonomy of lower administrative units in each region, strengthening the efficiency, accountability and capacity to increase health workforce. Although there is mention of strategic incentive packages for health workers, however, there are no details on what these packages include, coupled with a reported lack of consistency throughout the regions, health facilities, and among health workers [112]. Official documents

state that incentives have been a key topic of discussion, however, it is unclear the current status of incentive packages or labor conditions [112].

15. Ethiopia's efforts to increase its health workforce, includes expansion of educational and training opportunities. Public universities that offer health-related degrees reached 23,000 new enrollments by 2015/16. Educational institutions providing health science programs (public) also increased from 5 in 2003 to 35 in 2016, having that annual intake of medical students increased from 152 in 2000 to 3,537 for the period 2015/16 [112]. Specialty training programs have been developed in order to enhance retention strategies for the nursing workforce, having programs in neonatal, surgical, pediatrics, emergency, among others. However, there are no details if these course integrated climate-related health risks. Moreover, the country also has in-service training (IST) and continuing professional development (CPD) programs in place, aiming at improving capacities, motivation, and overall performance of health professionals. These courses are linked to career progression; however, it is not clear which areas or specific courses it provides and how many health workers have benefitted [112].

HEALTH INFORMATION AND DISEASE SURVEILLANCE

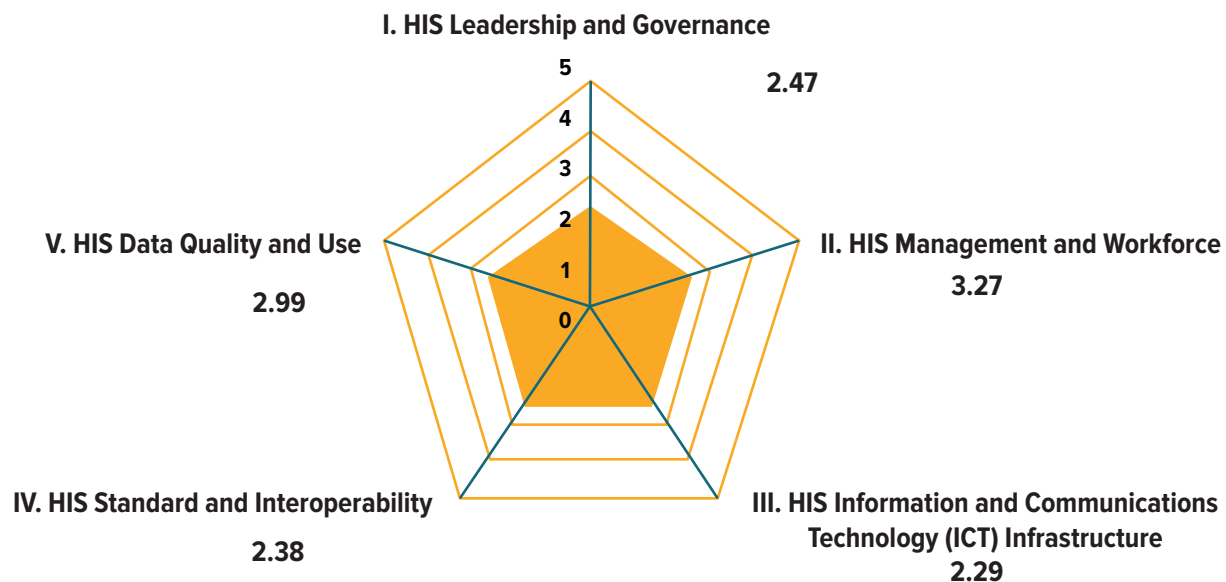
16. The Ministry of Health of Ethiopia (MoH) identified health information systems (HIS) as a key pillar of the health sector transformation plan for 2020-2025, with the aim to advance collection, analysis, presentation, and dissemination of information that could influence decision-making. The key platforms for capturing information in the health sector are

routine health management information (HMIS), District Health Information System (DHIS2), electronic community health information system (eCHIS) and public health emergency management (PHEM). National surveys are also additional sources of information that use high quality tools and follow global standards. In 2021, the MOH evaluated the strengths and areas of improvement for the current HIS and set the aspired status for 2024 [118]. The findings agree with a similar exercise conducted by the WHO in 2019 based on the Global Digital Health Index [119]. Figure 17 illustrates the status of HIS across five components of Ethiopia's health sector, with key needs highlighted across all areas of the HIS.

17. The Ethiopian Public Health Institute (EPHI) is proactive in surveillance of various diseases of local and global public health significance. The EPHI is the technical wing of the MOH, which is mandated to undertake Public Health Emergency Management (PHEM) among other thematic areas in addition to research, regional laboratory capacity building and training of health professionals (according to revised mandate in 2014). It uses emergency operation centers during serious epidemics and obtains health and other event information from respective health facilities on hours to days' timescales. PHEM uses dashboard for monitoring diseases of epidemic feature, which are mostly climate-sensitive in nature (e.g., malaria, cholera, meningitis, malnutrition, and dengue). The frequency of reporting is determined by requirements and according to guidelines of the World Health Organization and International Health Regulations (IHR) for various diseases. For example, malaria is reported weekly using WHO week definitions and compares previous subsequent years to learn and detect outbreaks in specific adminis-

FIGURE 17.

Evaluation of Ethiopia HIS across five health sector components [120]



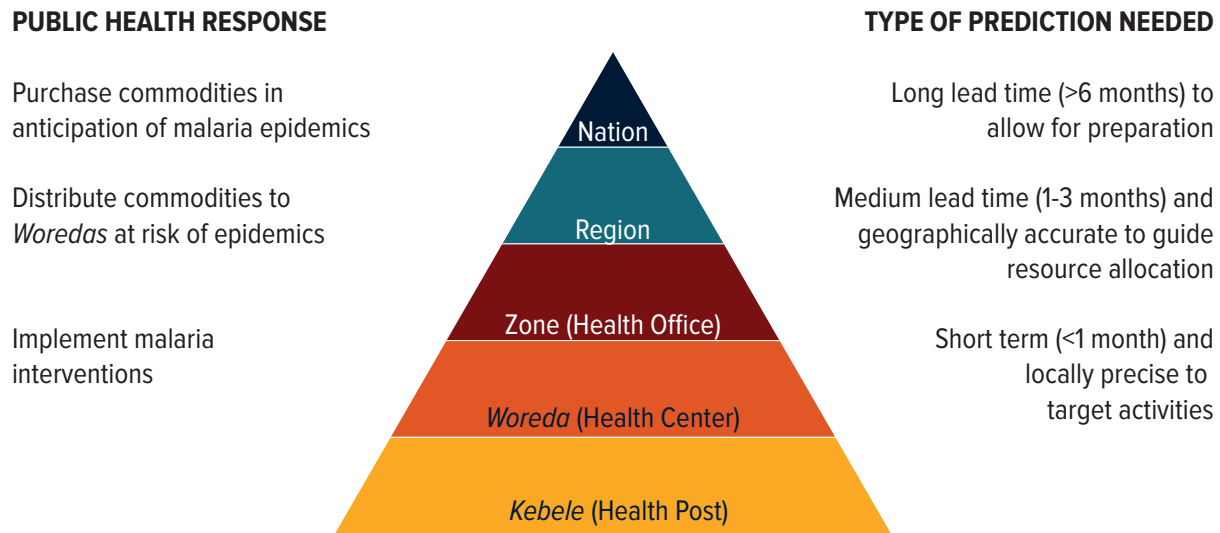
trative units (district, zone, and regions). EPHI has had good experience in using dashboards for surveillance of COVID-19 currently and Ebola in the past. Emergency Operations become functional notified and detected cases require national response, such as a disease outbreak beyond the capacity of local health facilities and respective regional states.

18. There have been initiatives under the MoH to use climate information to prevent climate sensitive diseases and to make necessary preparations to tackle the predicted disaster, or epidemic disease, with a high focus on malaria. As mentioned, the PHEM has a dashboard for surveillance of priority climate-sensitive diseases and gives regular updates to the Ministry of Health. Moreover, there have been substantial efforts to operationalize a malaria early warning system in Ethiopia. The EPIDEMIA project and associated tool has worked to address challenges to applying climate-driven models for malaria early

warning in Ethiopia [121]. Available sources of national-level malaria surveillance data have been examined to assess their suitability for supporting a national malaria early warning system [122] [123] and a pathway for scaling the EPIDEMIA project to the national level has been developed [124]. Figure 18 identifies public health responses to malaria warning and required types of predictions. Additionally, there are on-going efforts to improve detection of and response to infectious diseases, such as training of health professionals to manage the current Monkey Pox outbreak, however, there remains a need for improved surveillance and diagnostics (including specialized training and services) to manage current and future climate-sensitive health risks, such as mental health. Overall, the center for PHEM strives to improve the early notification and response as well as rehabilitation of the affected community, particularly in the case of internally displaced peoples (IDPs).

FIGURE 18.

Public health responses to malaria warning and required types of predictions [124]



Note: Levels at the top of the pyramid are largest in geographic area and population size, but fewer in number. At lower levels, more entities encompass smaller areas and fewer people.

ESSENTIAL MEDICAL PRODUCTS AND TECHNOLOGIES

19. Overall, Ethiopia has a relatively high availability of medical products and supplies, with a product score⁴ of 0.51, which was slightly higher than the regional average of 0.48 [125]. However, challenges remain, including lack of adequate medical storage conditions and wastage, particularly for health center and health posts. There are also issues with procurement, maintenance, and inventory management of medical equipment, along with a gap in testing the efficacy of generic drugs produced in Ethiopia, due to lack of bioequivalence centers [109].

20. Building local institutional capacity, particularly advanced laboratory techniques for detection and reporting of arbo-viral

diseases, as well as improving the quality of data and surveillance systems, is believed to support informed decision-making by local health authorities. Additional information on interaction of human and the natural environment to elucidate reservoirs and local transmission is required. Understanding the transmission cycles, including jungle (sylvatic), intermediate (savannah), and urban transmission of yellow fever, guide interventions [126], enabling the identification of the appropriate intervention designs.

HEALTH SERVICE DELIVERY

21. Overall, Ethiopia has seen significant advancements in health service delivery in the last two decades, resulting in improvements in several health outcomes [127]. Nevertheless, access to health services tends to disproportionately benefit those with greater economic means or higher levels of education,

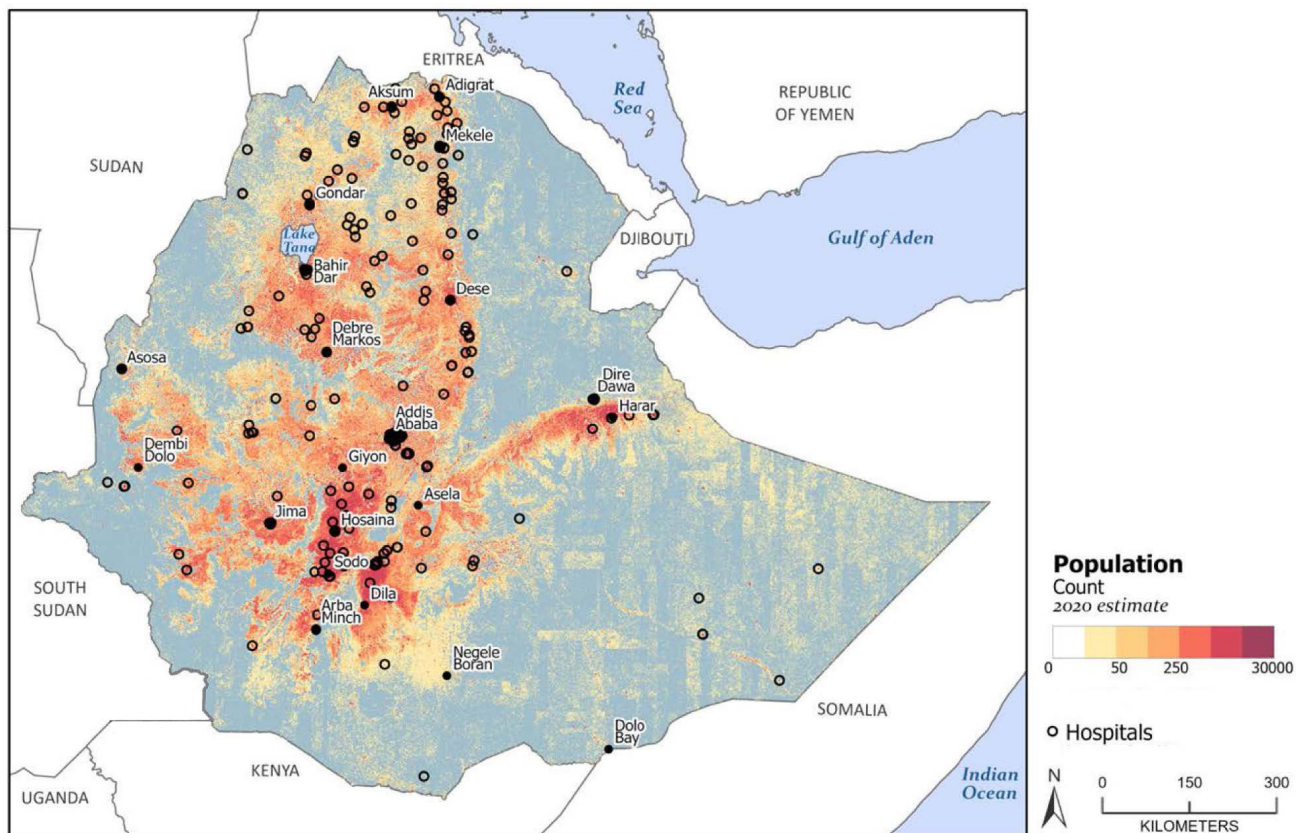
⁴ A score composed of indicators that include readiness of diagnostics and essential medicines, density of pharmacy professionals, and rate of blood donation.

despite governmental efforts to overcome financial barriers, such as subsidization of more than 80 percent of the cost in public health facilities and community-based insurance schemes [124].

22. In most areas of Ethiopia, health facilities (health posts, health centers and hospitals) were built in accordance with the conventional standards for developing countries [128]. This helps with preventing and managing existing and future diseases burden. Access to basic health care (measured by access to a Health Center) reached 96.1 percent in 2017 with the construction of new health centers and upgrading previous health posts and clinics to health centers [128]. However, access to healthcare can still be a challenge for some

areas of the country, with thousands of people living over 150 km away from a hospital, such as in Oromia region (Figure 19). Further, many existing health facilities are not equipped with the needed resources such as equipment, trained health professionals and essential infrastructure, such as safe and reliable water supply, electricity, means of communication, thus leaving many healthcare facilities exposed to climate change related disasters, including flooding casualties, drought induced diseases, epidemic climate-sensitive diseases (e.g., diarrhea, meningitis, malaria). Many of the public health facilities in Ethiopia still struggle with access to electricity and improved water sources, with several regions with below 50 percent access for health posts, health centers, and hospitals (Table 6).

FIGURE 19.
Population distribution and location of hospitals, 2020



Source: Oak Ridge National Laboratory

TABLE 6.

Public health facilities accessed electricity and improved water sources by region, 2014 [128]

REGION	ACCESS TO REGULAR ELECTRICITY (%)		ACCESS TO IMPROVED WATER SOURCES (%)	
	HEALTH POSTS	HEALTH CENTERS AND HOSPITALS	HEALTH POSTS	HEALTH CENTERS AND HOSPITALS
Tigray	44	64	40	86
Afar	50	70	55	45
Amhara	54	45	63	79
Oromia	18	49	39	74
Somali	15	78	40	48
Benishangul Gumuz	10	47	52	76
SNNP	24	50	39	72
Gambella	15	68	67	77
Harari	24	63	52	94
Addis Ababa	N/A	60	N/A	97
Dire Dawa	42	82	65	96

*Red indicates under 50% of healthcare facilities.

23. The Ethiopian Health Extension Programme (HEP) (the country's flagship for health service delivery) was designed to serve as a bridge to convey primary health services at community level. The HEP has 16 packages and majority of them deal with disease prevention and health promotion interventions. The HEP has obtained remarkable achievements such as increased institutional delivery, increased family planning utilization, increased latrine coverage, decreased malaria incidence, and decreased HIV incidence [129]. It was reported in 2021 that the Ministry of Health in Ethiopia has not yet implemented mental health services as part of integrated services, but it intends to do so having included these services into their health extension package. Barriers were identified, such as low political commitment, shortage of resources, non-functional referral system, lack of interest from private health service organizations, attitudinal problems from both the society and service providers,

and lack of consistent reporting system of the mental health problems [130].

24. The MoH has made strides to enhance the health sector's response to extreme weather events, such as floods and drought, as well as other public health emergencies. One important strategy has been the establishment of the Public Health Emergency Management Center, which coordinates and assists all efforts to improve the preparedness of the health sector to prevent or reduce the public health consequences of outbreaks of diseases, including malnutrition, natural disasters, industrial or technological accidents, displacement of populations, civil unrest, conflicts or acts of terrorism and any other emergency or disaster situations [127]. Additionally, the National Policy and Strategy for Disaster Risk Management (2013) outlines the framework for implementation of multi-sectoral, multi-hazard disaster management systems. The role of the

MoH is primarily centered on food shortage induced malnutrition affecting children and mothers and also other human epidemics associated with disasters [131].

FINANCING

25. Ethiopia has in place a Health Care Financing Strategy to enhance the countries public finance efforts in the health sector.

In 1998, health financing reform was introduced by the Federal Ministry of Health when it developed a Health Care Finance Strategy to increase resource mobilization, improve efficiency in the allocation of these resources, [132] and promote the sustainability of financing for health [133]. The strategy highlighted the need for cost sharing to support the government in financing health [133]. Ethiopia's most recent strategy, the National Health Care Financing Strategy, 2015 - 2035, prioritizes the reduction of out-of-pocket expenditure using health insurance schemes and introduced no fees for key services [134]. The National Health Accounts is used to monitor the finance strategy.

26. Over the last two decades, total health expenditure has been low and declining while out-of-pocket expenditure has been higher than public health expenditure.

Health financing in Ethiopia is mainly through government, private, and household expenditure. The country's public health expenditure has remained below the recommended share of 15 percent of the total budget required to strengthen health systems (according to the Abuja declaration) and is below the sub-Saharan average. Although current health expenditure per capita has increased from 5.38 percent in 2000 to 26.74 percent in 2019, [135] the health sector in the country remains under resourced. Health

expenditure as a percentage of GDP has also declined from 4.37 percent in 2000 to 3.24 percent in 2019 [135]. Household out-of-pocket (OOP) expenditure in Ethiopia is one of the highest in the world [136]. OOP expenditure is high at approximately 37.88 percent of current health expenditure, [135] higher than the recommended WHO threshold of 20 percent [134]. This has increased from 35.96 percent in 2000 and was highest in 2010 (46.54 percent of current health expenditure) [135]. Additionally, as a percentage of current expenditure, OOP expenditure (37.88 percent) was higher than domestic general government health expenditure (22.7 percent) in 2019 [135]. The high OOP expenditure has negative consequences for poorer households. Approximately, 46 percent of rural households faced high healthcare expenditure accounting for 10 percent of their total expenditure, while 94 percent were moved further into extreme poverty [136]. Nonetheless, the government has partnered with the private sector to enhance the efficiency of the health system as part of its health finance strategy [134].

27. Ethiopia has scaled up a community-based health insurance program, but risk pooling does not seem to account for climate and health related risks.

A country's health finance system such as health insurance schemes influences the level of risk pooling. In 2008, Ethiopia developed a health insurance strategy to support the development of social health insurance (SHI) for the formal sector and community-based health insurance (CBHI) for the informal [137]. As of 2014, the legal aspects of the SHI were being initiated while the CBHI was being piloted [137]. The CBHI benefit package includes curative and health services for families [138]. Following the success of the pilot CBHI, it has been scaled up to 350 woredas, such that 14.5

million people had health insurance in 2017 [138]. Although Ethiopia has in place a CBHI, it relies on heavy premium payments which are 70 percent of its revenue [139]. Increasing the risk pool can enhance the financial sustainability of the CBHI [140].

28. Climate financing in Ethiopia is low and shows a huge gap in budgeted versus actual spending. The majority of financing for climate is focused on adaptation activities (87 percent) compared to mitigation (13 percent) [141]. Between 2008 and 2012, the share of climate expenditure as a percentage of government expenditure ranged from 11 percent to 20.2 percent, representing a 1.8 percent and 2.3 percent share of GDP, respectively [141]. During the same period, finance credibility was poor as the difference between the budget and actual expenditure on climate was as low as 25 percent of actual expenditure as a share of what was budgeted [141].

29. Ethiopia faces a huge financing gap to respond to climate change. For instance, the Climate Resilient Green Economy strategy requires US\$ 7.5 billion a year for the country to respond to climate change, yet the government budgets approximately US\$ 440 million a year for climate change [141]. Additionally, climate expenditure was mainly concentrated in the Ministry of Agriculture and the Ministry of Water, Irrigation and Energy [141]. The Ministry of Health expenditure on climate

is low. Although, there was an increase in climate-related expenditure by the Ministry of Health since 2008, financing by the ministry was only 6 percent of total climate expenditure in 2011/12 [141].

30. Ethiopia is heavily reliant on donor funds, yet these funds are off-budget and hard to track. Federal capital expenditure is heavily reliant on donor finance. In 2017/18, it accounted for 85 percent of the federal capital health expenditure [134]. However, health resources received from donors are usually off-budget making it a challenge to track these resources [134]. With regards to climate financing, Ethiopia has received substantial resources from the Official Development Assistance (ODA) and donors, approximately US\$ 3.5 billion in 2011 [141]. The World Bank, African Development Bank, the United States and the UK are biggest providers of finance for climate change in Ethiopia [142]. The Green Climate Fund supported Ethiopia with US\$ 265 million and a total of more than US\$ 799 million was received from the Global Environment Facility as of 2021 [143]. Donor financing is also heavily focused on climate adaptation (64 percent) in Ethiopia [144]. However, despite receiving some support for climate change from donors (approximately 20 percent of funding from donors in 2011/12), there is still a huge financing gap to meet intended goals [141].

Ethiopia faces a huge financing gap to respond to climate change. For instance, the Climate Resilient Green Economy strategy requires US\$ 7.5 billion a year for the country to respond to climate change, yet the government budgets approximately US\$ 440 million a year for climate change.

TABLE 7.

Summary of the Health System Adaptive Capacity Gaps for Ethiopia

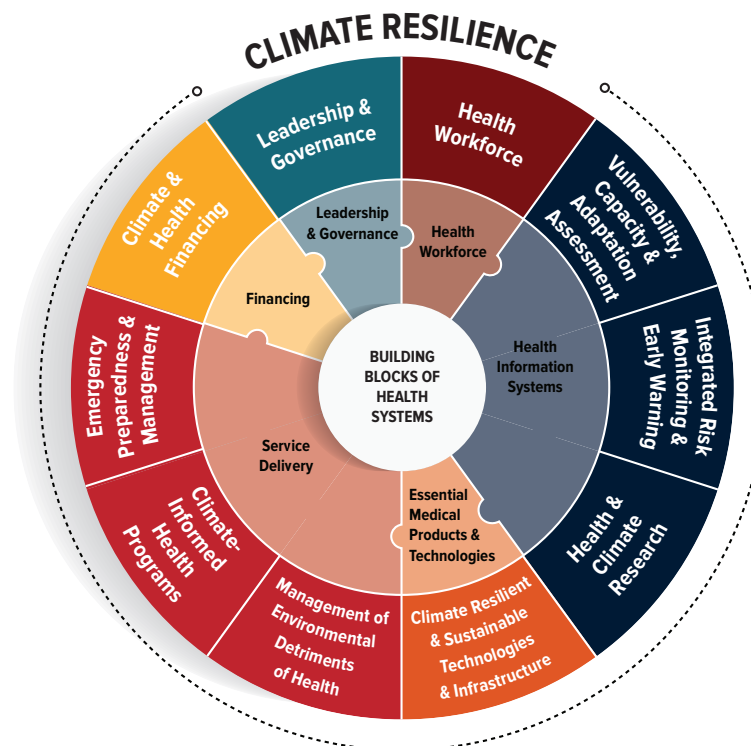
BUILDING BLOCK	SUMMARY OF GAPS IN ADAPTIVE CAPACITY
Leadership and Governance	• Prioritization of climate change and health risks and adaptation options in national policies and plans is high. • Coordination mechanisms (e.g., National Climate Change and Health Technical Working Group) could be strengthened to facilitate cross-sector action on climate change. • Implementation of climate change and health policies and plans, particularly at sub-national levels, has been slow and fragmented.
Health Workforce	• The health sector faces an imbalance in the number, skill mix and deployment of health workforce, including large urban-rural disparities. • A systematic approach for capacity development of health workforce in climate change, including development and integration of training materials is absent. • Knowledge, technical capacity, and resources of the health workforce to prevent and manage current and future climate-change related health risks remains unknown.
Health Information and Disease Surveillance Systems	• Health information and surveillance systems are currently not integrated and do not include climate/weather data or other environmental factors. • A climate-informed early warning system for malaria has been piloted, but scale and national operationalization has not been completed. • Data collection and analysis of climate-sensitive diseases at, district, and facility levels remains a challenge.
Essential Medical Products and Technologies	• Management and storage of medical products and supplies is lacking, particularly in rural health centers and posts. • Laboratory capacities and other health technologies in Ethiopia also need further assessment to better understand the ability to manage current and projected climate-sensitive diseases.
Health Service Delivery	• Many healthcare facilities lack essential services, including safe water and sanitation systems, and reliable electricity. • Climate-resilient healthcare facility and health infrastructure assessments are lacking, including adequate coordination across sectors to ensure climate risks are being incorporated into infrastructure planning. • Climate change and associated impacts are not mainstreamed into the operations of health programs at all levels. • Baseline information is lacking on key environmental determinants of health.
Health Financing	• Financing gaps exist to adequately respond to climate change impacts in the health sector, including budget versus spending. • Risk pooling does not account for climate change-related health risks. • Budgets within the health sector, including for climate change adaptation planning need to clarify amounts and the incorporation of climate change risks.

RECOMMENDATIONS TO ENHANCE HEALTH SYSTEM RESILIENCE TO CLIMATE CHANGE

1. **This section outlines a set of recommendations to enhance health system resilience and adaptation to climate change, including potential health interventions and strategies.** The recommended options are based on an assessment of both the magnitude of the current and projected climate-related health risks and the existing gaps in adaptive capacity to manage and/or prevent these risks. This section is organized using the 10 components of climate-resilient health systems (Figure 20) and drawing from consultations and review of all relevant governmental policies, as well as the World Bank HNP Climate and Health Guidance Note. See Annex B for a summarized menu of health adaptation recommendations across key health risks and Annex D for an extended list of recommendations for building a climate-resilient health system across the identified climate change-related health risks.

FIGURE 20.

WHO's Operational Framework for Building Climate-Resilient Health Systems [8]



COMPONENT 1: LEADERSHIP AND GOVERNANCE

Options to strengthen leadership and governance include:

- Integrate health into national and sub-national level climate adaptation planning with priorities being the finalization of the Health National Adaptation Plan (HNAP), next iteration of the National Adaptation Plan (NAP-Eth), as well as the next round of NDCs. This should include detailed descriptions of priority climate change-related risks, health sector adaptation options, and opportunities to link with non-health sectors. It will also be important to link with the National Framework for Climate Services, of which Ethiopia is currently at the planning and costing phase [145].
- Support the formalization and resourcing of the National Climate Change and Health Technical Working Group, led by the Ministry of Health, including establishment of regular meetings and increased involvement across sectors to facilitate effective implementation of policies, strategies, and plans. This may include signing a memorandum of understanding between the Ministry of Health and other key stakeholders at the national level, including other sectors such as agriculture, planning and development, and transportation, as well as clarification of the focal point on climate change and health in MoH to better facilitate coordination across sectors and departments.
- Advance / develop contextualized communication tools climate-related health risk and advocacy at all levels including the senior officials and politicians as well as the general public at higher risk. This may also include sensitizing health sector policy makers and

planners, using workshops and policy briefs, to use climate information to inform design of health sector programs and enhance day to day service delivery as well as during and after extreme weather events, such as flooding.

COMPONENT 2: HEALTH WORKFORCE

Options to strengthen the health workforce include:

- Develop educational and awareness raising materials and implement training for healthcare workers to better understand the health impacts of climate change, including the utilization of train the trainer (ToT) models. This may include capacity building activities, such as targeted training for health personnel to manage changes in vector-borne disease (especially malaria) and food insecurity/ under-nutrition, particularly as sub-national levels, as well as how to conduct epidemiological analyses of climate-sensitive diseases and vulnerability and adaptation assessments.

COMPONENT 3: VULNERABILITY, CAPACITY AND ADAPTATION ASSESSMENT

Options to strengthen vulnerability, capacity and adaptation assessments include:

- Utilize modeling techniques, including climate, disease, and economic scenarios to guide future vulnerability adaptation assessments. This could integrate outputs from tools currently under development by the World Bank including the Climate and Health Economic Valuation Tool (CHEVT) as well as others. These tools would make use of information collected in this and other CHVAs.

COMPONENT 4: INTEGRATED RISK MONITORING AND EARLY WARNING

Options to strengthen integrated risk monitoring and early warning systems include:

- Support expanded, enhanced, and electronic coverage of health surveillance for climate-sensitive diseases, for example in terms of geographic, population, and seasonal aspects. This would include linking with environmental/meteorological monitoring structures to develop climate-informed early warning systems and response mechanisms. For example, this could build on efforts to develop a climate-informed early warning system for malaria.

COMPONENT 5: HEALTH AND CLIMATE RESEARCH

Options to strengthen climate and health research include:

- Supporting research priorities for specific climate-related health risks, including studies on climate-resilient and nutritious crops, assessing extreme heat impacts among workers and interventions to improve occupational health, analysis of water demands under different climate scenarios, and assessing the influence of frequency, timing, and magnitude of rainfall on VBDs, as well as the concomitant role between VBDs and under-nutrition in vulnerable populations given high rates of food insecurity.

COMPONENT 6: CLIMATE-RESILIENT AND SUSTAINABLE TECHNOLOGIES AND INFRASTRUCTURE

Options to strengthen the climate resilience of health technologies and infrastructure include:

- Develop and implement national building codes/permits for healthcare facilities, including retrofitting, refurbishing, and maintaining existing health infrastructure. Importantly this should include the incorporation of climate risk projections into these codes/permits for examples to include siting and construction, functioning and operation, energy and water supplies, storm drains and sewers, and sanitation services of health care facilities, as well as a focus on improving the transportation network to ensure access to facilities during extreme weather events.

Actions have also been identified that will contribute to enhanced sustainability and reduced greenhouse gas emissions in the health sector such as:

- Assess the carbon footprint of Ethiopia's health sector.
- Prioritize sustainability in selection of health system procurement strategies procedures and products, this would include focus on incorporation of low-carbon, energy efficient technologies, such as photovoltaic cells, solar-powered machinery, vaccine chains and water pumps.
- Promote modern energy cooking solutions (MECS) such as low emission cookstoves to reduce solid fuel use and household air pollution.
- Develop regulations that support sustainable healthcare waste management (e.g., shifting from medical waste incineration and promoting recycling of non-hazardous waste at facility levels where possible).

COMPONENT 7: MANAGEMENT OF ENVIRONMENTAL DETERMINANTS OF HEALTH

Options to strengthen the management of environmental determinants of health include:

- Develop improved national regulations and policies on key environmental health services and determinants (e.g., drinking water, air quality, food system, housing, transport, energy, and waste management). This could include the establishment and maintenance of a climate and environmental health database to support development of national regulations on the management of environmental health services (e.g., water supply, sanitation, and air quality) and perhaps leveraging opportunities to engage the World Meteorological Organization Africa headquarters located in Addis Ababa.

COMPONENT 8: CLIMATE-INFORMED HEALTH PROGRAMS

Options to strengthen climate-informed health programs include:

- Strengthen primary health care and existing programs through actions to ensure these systems have improved adaptive capacity, including knowledge and resources to manage current and future climate change-related risks. Activities may include revised public health program standard operating procedures (SOPs) to incorporate responses to climate risks and delivery of interventions, as well as mainstreaming of climate change risks into relevant policies and operational plans for vector-borne disease, water-related disease, and nutrition programs.

COMPONENT 9: EMERGENCY PREPAREDNESS AND MANAGEMENT

Options to strengthen emergency preparedness and management for climate change related disasters include:

- Establish seasonal and sub-seasonal climate outlooks (Ministry of Health in collaboration with Ethiopian Meteorological Institute) to inform disease control / prevention programs ahead of potential extreme weather events, and facilitate multisectoral engagement with first-responders, disaster management authorities, community-based groups, to conduct outreach and awareness regarding climate-sensitive diseases.

COMPONENT 10: CLIMATE AND HEALTH FINANCING

Options to strengthen climate and health financing include:

- Ensure strategic purchasing (e.g., increasing equitable distribution of resources) includes climate considerations [146]. This should be tailored to include climate considerations across the national and sub-national levels. The impact of climate on utilization of resources needs to be factored into provincial and district health investment plans to build climate resilience at sub-national levels and support continued investment in poverty reduction, health equity promotion, and increased access to essential services. This should also incorporate mitigation activities such as solarization of health facilities.

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ANNEXES

ANNEX A. ADAPTIVE CAPACITY AND CLIMATE CHANGE-RELATED HEALTH RISKS GAP ANALYSIS

HEALTH SYSTEM BUILDING BLOCKS	SELECTED CLIMATE CHANGE-RELATED HEALTH RISKS				
	FOOD SECURITY AND NUTRITION	VECTOR-BORNE DISEASE	WATER-BORNE AND WATER-RELATED DISEASES	HEAT-RELATED MORBIDITY AND MORTALITY	MENTAL HEALTH AND WELL-BEING
Leadership and Governance	Climate change integration into strategic planning and interventions for food security and nutrition are lacking.	Multi-institutional coordination for malaria early warning system scale up is lacking.	Strengthen link with MoH across sectors to improve WASH climate-resilient infrastructure. Sub-national interventions lacking.	No Heat-Health Action Plan or Strategy. Health impacts of extreme heat mentioned in climate change or health sector policies or planning, although no interventions highlighted.	Addressing stigma around mental health needs improving, including link with climate-related disasters, and improved care for mental health issues.
Health Workforce	Climate change not incorporated into training models across programs	Training linking climate / weather variables to VBD, particularly epidemiology and the use of climate / weather data at sub-national levels.	Baseline understanding of WASH and climate relationship and interventions is needed, including building from	MoH staff have not completed training on identification and clinical responses for extreme heat.	Specialist training and services needed for mental health.
Health information and disease surveillance system	Further assessment needed to understand relationships between climatic factors and nutrition / food insecurity - building from WFP surveys.	Improving basic surveillance for VBD needed and further integration of climate / meteorological data for early warning.	Climate data not integrated into HIS. No risk assessment for WBD and climate change. No EWS for water-borne diseases.	MoH does not record heat-attributable mortality. No mapping of urban hot spots to identify at-risk populations. No EWS for extreme heat.	No baseline data on mental health related to climate change. Further exploration of community-centered resilience building and targeting vulnerable populations needed.
Essential medical products, technologies, and infrastructure	No baseline information on equipment / medication related to under-nutrition, including new technologies related to sustainable agriculture.	Laboratory, testing, and control capabilities need to continue to be strengthened for effective malaria response and elimination.	Distribution of essential medications (e.g., vaccines) are lacking in rural / remote areas.	Healthcare facilities have not been assessed to determine potential risks related to extreme heat, and cooling measures have not been implemented.	Need for need for improved surveillance and diagnostics for mental health.

HEALTH SYSTEM BUILDING BLOCKS	SELECTED CLIMATE CHANGE-RELATED HEALTH RISKS				
	FOOD SECURITY AND NUTRITION	VECTOR-BORNE DISEASE	WATER-BORNE AND WATER-RELATED DISEASES	HEAT-RELATED MORBIDITY AND MORTALITY	MENTAL HEALTH AND WELL-BEING
Health service delivery	Strengthening nutrition programs in remote, rural areas needed, particularly before, during, and after drought.	Climate change not incorporated into standard operating procedures for VBD. Community-based interventions / awareness building can include link between VBD and climate change.	Lacking baseline information on safe WASH in healthcare facilities and interventions needed to improve resilience to climate change.	There are no extreme heat programs in NDoH – extreme heat not included in DRM plans / operations.	Assessment and treatment of mental health and well-being not included in health services.
Financing	Climate-smart agriculture systems, including water harvesting and irrigation to manage rainfall variability needed.	Surveillance of malaria and dengue need investment as well as additional analysis of VBD risk associated with climate change.	Distribution of funds for improved WASH, especially in rural areas is needed.	Extreme heat not prioritized in health sector budget planning.	Increases in resources allocated to mental health within MoH needed.

ANNEX B. HEALTH ADAPTATION RECOMMENDATIONS: MENU OF OPTIONS

COMPONENT	FOOD SECURITY AND NUTRITION	VECTOR-BORNE DISEASE	WATER RELATED DISEASES	HEAT-RELATED MORBIDITY AND MORTALITY	MENTAL HEALTH AND WELL-BEING
Component 1: Leadership and Governance	Incorporation of climate change risks into food security and nutrition strategic plans, including sustainable agriculture efforts.	Establishment of a multi-institutional steering committee to monitor scale-up and make key implementation decisions for climate-informed early warning system.	Promotion of climate-resilient water safety planning.	Develop and implement national heat health policy and city-level plans.	Development of a national mental health strategy and action plan.
Component 2: Health workforce	Incorporation of educational materials on climate change impacts on food security and nutrition into health worker training.	Training at sub-national levels to enhance capacity of epidemiological analysis, as well as knowledge of climate change-related factors.	Awareness raising for health workers climate change impact on WASH and WBD.	Conduct heat-health training for health workers. Ensure occupational heat exposures are managed.	Training for community health workers on mental health awareness and interventions, especially following extreme weather events.
Component 3: Vulnerability, capacity and adaptation assessment	Vulnerability assessment of nutrition to climate change. Assessment of nutrition benefits of climate-smart agricultural interventions.	District and community level assessments to better understand local risks related to VBD and capacity to manage outbreaks.	Vulnerability assessment to water shortages, rainfall extremes, unpredictable river flows, and baseline WASH coverage in healthcare facilities	Conduct assessment for high-risk groups at city-level, including informal settlements and incorporate economic analyses.	Further exploration of impact of climate change on mental health, as well as community-based resilience building interventions.
Component 4: Integrated risk monitoring and early warning	Development and inclusion of long-term strategies for nutrition interventions into drought early warning system	Scale and operationalization up of climate-informed early warning system for malaria	Integration of climate/weather information with WBD surveillance systems to forecast outbreaks.	Heatwave alert systems for urban and rural populations.	Develop mental health surveillance system.
Component 5: Health and climate research	Analysis of long-term effects of food insecurity on health and economy.	Conduct additional climate change modeling studies to estimate malaria risk projections and inform adaptation decisions.	Modeling water security/demand projection under different climate scenarios and impact on WBD.	Studies to further explore impacts of extreme heat on health systems, including urban heat island mapping.	Studies on mental health impact of climate change and potential community-level interventions.
Component 6: Climate-resilient and sustainable technologies and infrastructure	Improved drainage systems in crop fields at risk to floods. Exploration of smart-agriculture and crop diversification practices.	Improve laboratory capabilities for testing and diagnosis of endemic as well as novel and re-emerging diseases. Develop a list of essential medicines needs for VBD outbreaks.	Improved WASH systems in healthcare facilities to withstand extreme weather events (e.g., drainage systems and healthcare waste management).	Space cooling in healthcare facilities to prevent overheating and protect IT and equipment. Energy efficient or passive measures of cooling to reduce energy costs.	Support development of mental health centers to support distribution of services in rural areas.

COMPONENT	FOOD SECURITY AND NUTRITION	VECTOR-BORNE DISEASE	WATER RELATED DISEASES	HEAT-RELATED MORBIDITY AND MORTALITY	MENTAL HEALTH AND WELL-BEING
Component 7: Management of environmental determinants of health	Community-led efforts to map food insecurity and inform interventions (e.g., gardening programs) to improve the food system in a changing climate.	Community awareness campaigns to increase awareness of climate sensitivity of VBD and engage vulnerable groups on outbreak prevention.	Improve household water security and sanitation practices.	Housing standards and urban planning (built environment) to reduce heat risks and improve water security. Occupational health management.	Engagement with communities to assess and improve mental health and well-being, including reducing stigma and building awareness.
Component 8: Climate-informed health programs	Interventions involving the establishment of gardens or food growing opportunities. Community mediated delivery of nutrition services including screening.	Incorporation of climate change information into VBD prevention and outbreak response SOPs.	SOPs for drinking water and sanitation provision. Public awareness-raising campaigns are conducted on hygiene, particularly handwashing.	Ensure heat risks are incorporated into maternal health guidance, guidance for NCD (e.g., diabetes management).	Mental health program developed in MoH.
Component 9: Emergency preparedness and management	Food production and distribution chain is reinforced to withstand impacts from extreme weather events.	Inclusion of VBD disease outbreaks into disaster risk management plans at national, regional, district, and community levels.	Develop WASH-focused emergency preparedness and response plans, including stockpiling and distribution plan for supplies (e.g., purifiers, safe water storage)	Extreme heat included into disaster risk management operations.	Mental health impacts related to extreme weather events incorporated into disaster risk management planning.
Component 10: Climate and health financing	Investments in dissemination of crop varieties and breeds adapted to changing climatic condition.	Formation of proposals for external donors to support improved control of VBD, particularly malaria .	Allocate resources to build climate-resilient WASH district level operation plans.	Financing of sustainable cities/cool cities that address heat risks. Other interventions related to heat-health responses (e.g., cool roofs).	Strengthened resource allocation for improved mental health services.

ANNEX C. ADAPTIVE CAPACITY RAPID ASSESSMENT

This information represents an initial review and will need to be confirmed with additional engagement with the stakeholders).

LEADERSHIP AND GOVERNANCE				
Questions	Assessment			
	Yes	Partial	No	N/A
1.1: Does the country have a national climate change and health plan / strategy?				
1.2: Is health mentioned as a priority in the Nationally Determined Contributions (NDCs)?				
1.3: Is there a designated focal point responsible for health and climate change in their ministry of health?				
1.4: Is there a multi-sectoral technical working group/committee focused on climate change and health?				
1.5: Does the MoH actively participate in climate change coordination and/or working groups?				
1.6: Is there a MOU between the MoH and key climate change related Ministries / Departments (e.g., Environment, Meteorological Services, Agriculture, Water)?				
1.7: Are decision-makers (both within MoH and outside) aware of climate change and health risks and potential adaptation options?				
1.8: Does relevant information related to climate change and health risks and adaptation reach key stakeholders across sectors?				
1.9: Is climate change included in health plans at sub-national levels?				
HEALTH WORKFORCE				
Questions	Assessment			
	Yes	Partial	No	N/A
2.1: Are there dedicated full-time staff devoted to climate change and health?				
2.2: Are the number of healthcare workers above 4.5 per 1000?				
2.3: Are health workers adequately distributed between urban and rural areas?				
2.4: Is the health workforce aware of the health risks of climate change?				
2.5: Are there capacity building programmes focused on climate change and health within the Ministry of Health?				
2.6: Have MoH staff received training on climate change and health in the last two years?				
2.7: Does the health workforce have the technical capacity to interpret and utilize climate change information (e.g., scenarios, projections, forecasts) to inform planning / decision-making?				
2.8: Is climate change and health included in the educational curriculum (e.g., schools of public health, medicine, nursing)?				
2.9: Are context or country specific climate change and health training / educational materials for the health workforce?				

HEALTH INFORMATION AND DISEASE SURVEILLANCE SYSTEM

Questions	Assessment			
	Yes	Partial	No	N/A
3.1: Has the country completed a climate change and health vulnerability and adaptation or risk assessment?				
3.2: Do surveillance systems exist for climate-sensitive diseases (e.g., heat related illnesses, VBD, WBD)?				
3.3: Does the country have a centralized monitoring system for climate-related diseases?				
3.4: Do health surveillance systems integrate meteorological and/or environmental information?				
3.5: Are there efforts from the MoH to utilize national climate / meteorological information?				
3.6: Does the country have a climate-informed early warning system for any health risks?				
3.7: Are there early warning systems in place for climate change related extreme events / hazards? (e.g., flooding, drought, storms)?				
3.8: Does the Ministry of Health coordinate with disaster/hazard focused early warning systems?				

ESSENTIAL MEDICAL PRODUCTS, TECHNOLOGIES, AND INFRASTRUCTURE

Questions	Assessment			
	Yes	Partial	No	N/A
4.1 Has the country's healthcare facilities been assessed for climate resilience?				
4.2 Are health facilities accessible for rural communities?				
4.3: Do healthcare facilities implement measures to remove mosquito breeding sites?				
4.4: Have healthcare facilities employed adaptive measures to protect against climate change related hazards (e.g., flood walls or drainage systems)?				
4.5: Does the national laboratory have the capacity to conduct diagnostic tests for climate-sensitive diseases?				
4.6: Are building codes for healthcare facilities to protect against climate change related hazards in place and enforced?				
4.7: Have healthcare facilities implemented 'greening' activities (e.g., tree planting, cooling designs)?				
4.8: Are there efforts to incorporate long-term planning (e.g., urban design) to reduce climate change and health impacts?				
4.9: Are health facilities adequately equipped to prepare for and respond to climate change related hazards (e.g., stockpile of medical/emergency supplies)?				

HEALTH SERVICE DELIVERY				
Questions	Assessment			
	Yes	Partial	No	N/A
5.1: Has the country enacted legislation mandating universal healthcare coverage?				
5.2: Are there climate change specific health programmes underway in the country?				
5.3 Does health service delivery have contingency measures for extreme weather events e.g., floods, storms, heatwaves)?				
5.4: Does current public health planning consider climate change information (e.g., scenarios, projections, forecasts)?				
5.5: Has the MoH implemented any climate-health awareness campaigns to increase public awareness?				
5.6: Is there access to safe WASH for over 80 percent of the country?				
5.7: Do over 80 percent of healthcare facilities have access to safe WASH and health-care waste removal / storage?				
5.8: Have multi-hazard risk assessments been conducted in the country?				
5.9: If conducted, do multi-hazard risk assessments include potential health risks?				
FINANCING				
Questions	Assessment			
	Yes	Partial	No	N/A
6.1: Is the Ministry of Health currently receiving international funds to support climate change and health work?				
6.2: Is there dedicated funding within the MoH for climate change and health activities?				
6.3: Is the health expenditure percentage of GDP above WHO recommendation?				
6.4: Is the national health budget dependent on donors or foreign aid?				
6.5: Are there climate considerations in the national health budget?				

ANNEX D. LONG LIST OF RECOMMENDATIONS

COMPONENT 1: LEADERSHIP AND GOVERNANCE

Options to strengthen leadership and governance include:

National (Climate Change)

- Integrate health into national level climate adaptation planning with a priority being the iteration of the National Adaptation Plan, as well as the next round of NDCs. This should include detailed descriptions of priority climate change-related risks, health sector adaptation options, and opportunities to link with non-health sectors, as well as utilize the National Framework for Climate Services.
- Utilize the National Climate Change and Health Technical Working Group, led by the Ministry of Health to increase engagement through the formalization, including regular meetings and increased involvement across sectors to facilitate effective implementation of policies, strategies, and plans. This may include signing a memorandum of understanding between the Ministry of Health and other key stakeholders at the national level, including other sectors such as agriculture, planning and development, and transportation.
- Advance / develop contextualized communication tools climate-related health risk and advocacy at all levels including the senior officials and politicians as well as the general public at higher risk. This may also include increasing awareness among policymakers and the private sector about the impact of climate change on health, and the environmental determinants of health.

National (Health sector)

- Finalize Health National Adaptation Plan (HNAP) which should incorporate all available evidence and senior endorsement to facilitate implementation. This should also be closely aligned with the National Adaptation Plan, serving as the health component of the NAP to facilitate integration and enable multi-sectoral approaches to be implemented.
- Systematically integrate adaptation activities to respond to identified climate-related health risks when updating the Health Sector Transformation Plan II (2020-2025), as well as work to incorporate stronger climate and health actions into at-risk programs, such as food security, nutrition, WaSH, malaria and other climate-sensitive diseases.
- Clarify the unit / focal point on climate change and health in MoH to better facilitate coordination across sectors and departments.
- Develop and deliver climate and health related workshops and national policy briefs aimed at senior health sector policymakers, as well as with other key sectors, to advocate and develop climate and health policies and plans at the national level. This may include sensitizing health sector policy makers and planners to use climate information to inform design of health sector programs and enhance day to day service delivery as well as during and after extreme weather events, such as flooding.

Sub-national

- Develop sub-national adaptation plans, including at *Woreda* (district) and city-levels for climate change and health to enable prioritization of adaptation needs and ensure allocation of sufficient financial resources for implementation.

COMPONENT 2: HEALTH WORKFORCE

Options to strengthen the health workforce include:

- Conduct a workforce climate and health needs and knowledge assessments to integrate climate change-related impacts into workforce planning. This would include considerations of the size of the health workforce, the skill mixes and the geographical distributions of personnel needed to meet expected health needs (e.g., addressing urban-rural disparities).
- Create a national curriculum that integrates climate-related health threats into medical and nursing schools as well as for all other health professionals to ensure the health workforce for tomorrow have the knowledge and skills to deliver health care in a changing climate.
- Develop educational and awareness raising materials and implement training for healthcare workers to better understand the health impacts of climate change, including the utilization of train the trainer (ToT) models. This may include capacity building activities, such as targeted training for health personnel to manage changes in vector-borne disease (especially malaria) and food insecurity/under-nutrition, particularly at sub-national levels, as well as how to conduct epidemiological analyses of climate-sensitive diseases and vulnerability and adaptation assessments.

COMPONENT 3: VULNERABILITY, CAPACITY AND ADAPTATION ASSESSMENT

Options to strengthen vulnerability, capacity and adaptation assessments include:

- Continue to conduct climate change and health vulnerability and adaptation assessments to capture new information and engage stakeholders, including conducting more advanced analyses, and prioritization of adaptation interventions. Assessments should be repeated

at least every five years. This could include further exploration of impacts and adaptation at sub-national levels, including evaluation of adaptation interventions, as well as reviewing the climate resilience of current healthcare infrastructure, such as impacts from extreme weather events such as flooding (flash and riverine).

- Utilize modeling techniques, including climate, disease, and economic scenarios to guide future vulnerability adaptation assessments. This could integrate outputs from tools currently under development by the World Bank including the Climate and Health Economic Valuation Tool (CHEVT) as well as others. These tools would make use of information collected in this and other CHVAs.
- Review the extent to which current health information systems incorporate meteorological variables for climate-sensitive diseases, notably malaria and other vector-borne diseases.

COMPONENT 4: INTEGRATED RISK MONITORING AND EARLY WARNING

Options to strengthen integrated risk monitoring and early warning systems include:

- Support expanded, enhanced, and electronic coverage of health surveillance for climate-sensitive diseases, for example in terms of geographic, population, and seasonal aspects. This would include linking with environmental/meteorological monitoring structures to develop climate-informed early warning systems and response mechanisms. For example, this could build on efforts to develop a climate-informed early warning system for malaria.
- Support hospitals to update their admissions and emergency case records to track heat-related morbidity and mortality, as well as other climate-sensitive diseases, starting

with Afar, Somali, and Gambela regions, which are projected to experience increased in heat index and tropical nights.

- Develop/improve/expand early warning systems for extreme weather events, such as heatwaves and flooding, to better integrate and disseminate health information (e.g., vector-borne and water-related disease outbreaks following flooding events) and link with disaster risk management and other key stakeholders.
- Review extent to which human, animal and plant disease surveillance systems are integrated and incorporate climate factors to ensure a One Health approach is utilized and strengthened.
- Collect information to establish and centralize agreed baselines for monitoring vulnerable populations/regions and existing or new health-related human resource, technical and health services delivery capacity, to be linked with the national climate change and health action plan (e.g., HNAP).
- Support the identification and/or development of indicators to measure climate change and health impact and response capacity to be integrated into national and sub-national monitoring systems. This would also support future climate change and health vulnerability and adaptation assessments.

COMPONENT 5: HEALTH AND CLIMATE RESEARCH

Options to strengthen climate and health research include:

- Continue to develop research partnerships (e.g., national and international academic institutions) to conduct studies and projects on key climate change and health topics, such as:

- modelling studies to quantitative current and projected burden of climate-sensitive diseases;
 - economic analyses to better understand healthcare costs related to climate change;
 - the quantification of health co-benefits of climate change mitigation actions;
 - operational research to test and evaluate the implementation of evidence-based interventions, such as targeted resource deployment for extreme weather events; and
 - development and testing of contextualized climate change and health risk communication materials and dissemination approaches.
- Additionally, research priorities for specific climate-related health risks may include studies on climate-resilient and nutritious crops, assessing extreme heat impacts among workers and interventions to improve occupational health, analysis of water demands under different climate scenarios, and assessing the influence of frequency, timing, and magnitude of rainfall on VBDs, as well as the concomitant role between VBDs and under-nutrition in vulnerable populations given high rates of food insecurity.

COMPONENT 6: CLIMATE-RESILIENT AND SUSTAINABLE TECHNOLOGIES AND INFRASTRUCTURE

Options to strengthen the climate resilience of health technologies and infrastructure include:

- Conduct an assessment of the climate vulnerability of current health infrastructure in Ethiopia, including closely linked systems (e.g., transportation, energy, and water and sanitation systems and infrastructure). This could include agreeing on a minimum threshold for health

care infrastructure and build from plans to conduct an assessment of healthcare facilities using the WHO guidance on climate resilient and environmentally sustainable in Ethiopia.

- Assess current laboratory capacities to diagnose current and future climate-related diseases, particularly emerging and reemerging communicable diseases, such as vector-borne diseases (e.g., dengue and chikungunya), as well as NCD burdens.
- Develop and implement national building codes/permits for healthcare facilities, including retrofitting, refurbishing, and maintaining existing health infrastructure. Importantly this should include the incorporation of climate risk projections into these codes/permits for examples to include siting and construction, functioning and operation, energy and water supplies, storm drains and sewers, and sanitation services of health care facilities, as well as a focus on improving the transportation network to ensure access to facilities during extreme weather events.
- Support the integration of new and innovative technologies to monitor environmental change (e.g., satellite imagery) to inform measures that will improve the performance of the health system, for example to direct support local health capacity planning to respond to anticipated increases in water-related diseases and food insecurity due to climate change. Other examples would relate to drought and nutrition, precipitation, heat, humidity and VBDs, as well as mapping air quality impact on health outcomes. Mental health services should also need to be considered.
- Introduce sustainable cooling measures (e.g., painting roofs white, increasing natural ventilation, integrating solar and biomass energy sources) for health care facilities and laboratories, which enhance energy efficiency, space

cooling, medical cold chains and ensure sustainable refrigerant technologies are used. These measures should follow a hierarchy of interventions starting from passive measures such as building design and vegetative shading through to more active technologies such as powered air conditioning as a secondary option.

- Development of structures to integrate health and climate considerations into urban design to reduce the threat of urban heat islands with a focus on informal settlements. This could involve strengthening health impact assessments through specific initiatives such as continued support for urban tree planting in cities, cool roof interventions (e.g., painting roofs white).

Actions have also been identified that will contribute to enhanced sustainability and reduced greenhouse gas emissions in the health sector such as:

- Assess the carbon footprint of Ethiopia's health sector.
- Prioritize sustainability in selection of health system procurement strategies procedures and products, this would include focus on incorporation of low-carbon, energy efficient technologies, such as photovoltaic cells, solar-powered machinery, vaccine chains and water pumps.
- Promote modern energy cooking solutions (MECS) such as low emission cookstoves to reduce solid fuel use and household air pollution
- Develop regulations that support sustainable healthcare waste management (e.g., shifting from medical waste incineration and promoting recycling of non-hazardous waste at facility levels where possible).

COMPONENT 7: MANAGEMENT OF ENVIRONMENTAL DETERMINANTS OF HEALTH

Options to strengthen the management of environmental determinants of health include:

- Develop improved national regulations and policies on key environmental health services and determinants (e.g., drinking water, air quality, food system, housing, transport, energy, and waste management). This could include the establishment and maintenance of a climate and environmental health database to support development of national regulations to manage environmental health services (e.g., water supply, sanitation, food safety, etc.).
- Map areas using unsafe drinking water and unimproved sanitation facilities, and assess service delivery gaps, and investment in improved drinking water, sanitation, and sewage infrastructure to improve water quality and reduce climate-driven exposures.
- Establish an improved centralized healthcare and medical waste management system that can withstand the impacts of extreme weather events.
- Support community led efforts to improve sanitation practices and controls to prevent water and foodborne diseases, as well as communicate the potential climate change-related risks.
- Increase support and integration with non-health sector (e.g., energy, agriculture, fisheries, industry, water supply and sanitation, transport, and urban and rural planning) focused interventions. This could include, for example, promotion of sustainable and climate-smart agricultural practices by smallholder farmers, appropriate modelling tools to assist strategic planning of water resources under climate change, and/or technical guidelines that incorporate climate change to increase supportive supervision, monitoring and testing of potable water and sanitation services.

COMPONENT 8: CLIMATE-INFORMED HEALTH PROGRAMS

Options to strengthen climate-informed health programs include:

- Use mainstream and social media, to spread awareness and issue warnings related to preventive measures to improve population health literacy related to climate sensitive health risks.
- Engage community groups (focusing on youth and women's groups) to support dialogue and development of prospective climate and health programs and policy options as well as integration into the planning and support of health promotion programs directed towards climate-related health threats. This could include mobilizing communities to better adapt to the health consequences of climate change, as well as other impacts.
- Strengthen primary health care and existing programs through actions to ensure these systems have improved adaptive capacity, including knowledge and resources to manage current and future climate change-related risks. Activities may include revised public health program standard operating procedures (SOPs) to incorporate responses to climate risks and delivery of interventions, as well as mainstreaming of climate change risks into relevant policies and operational plans for vector-borne disease, water-related disease, and nutrition programs.

COMPONENT 9: EMERGENCY PREPAREDNESS AND MANAGEMENT

Options to strengthen emergency preparedness and management for climate change related disasters include:

- Establish a national risk register that includes climate change related risks and if necessary, implement a process of national risk assessment

to enable the prioritization of climate-related health risks alongside other national level threats.

- Enhance contingency planning for deployment and response (at national, regional, and district levels) for acute climate shocks, such as flooding and consequent disease outbreaks, as well as longer-term climate stressors such as drought. This should include integrating climate-related health considerations into district-level and community-level disaster management plans to support stakeholders in organizing activities relating to the preparedness of emergency responses, as well as stockpiling and distribution plans to support disaster response supplies (e.g., water purifiers and safe water storage containers).
- Establish seasonal and sub-seasonal climate outlooks (Ministry of Health in collaboration with Ethiopian Meteorological Institute) to inform disease control / prevention programs ahead of potential extreme weather events, and facilitate multisectoral engagement with first-responders, disaster management authorities, community-based groups, to conduct outreach and awareness regarding climate-sensitive diseases.
- Conduct scenario-based simulation exercises with sub-national health workers to enhance planning and response to health emergencies that are outside the range of historical experience.

COMPONENT 10: CLIMATE AND HEALTH FINANCING

Ultimately establishing the below recommendations seeks to reach a ‘climate-smart’ UHC approach through the lens of health financing, in line with government priorities. Options to strengthen climate and health financing include:

- Establish a budget line item at the national level to finance critical preparedness activities and adaptation interventions.
- Initiate pooling health funds to cover climate-related health risks. This could include consideration of a pre-payment mechanism providing financial protection for climate-related health impacts through the pooling of resources.
- Ensure strategic purchasing (e.g., increasing equitable distribution of resources) includes climate considerations⁵. This should be tailored to include climate considerations across the national and sub-national levels. The impact of climate on utilization of resources needs to be factored into provincial and district health investment plans to build climate resilience at sub-national levels and support continued investment in poverty reduction, health equity promotion, and increased access to essential services. This should also incorporate mitigation activities such as solarization of health facilities.
- Explore financial benefits of health co-benefits of climate action. The economic benefits of mobilization of financial resources in Ethiopia aim to support the health sector in assessing the co-benefits of climate action in other health-determining sectors and to identify climate actions that bring greatest benefits to health.
- Seek international and external donor funding opportunities and mechanisms. This can include the Green Climate Fund, Global Environment Facility, Adaptation Fund for dissemination towards health-based adaptation measures, controlling climate-sensitive diseases, research projects, and mitigation projects, including nationally determined contributions. Additionally, there should be efforts to improve engagement from the health sector with on-going and/or planned climate change adaptation projects.

⁵ WHO. Promoting Strategic Purchasing. Accessed at <https://www.who.int/activities/making-purchasing-more-strategic>

ANNEX E. METHODS FOR THE ESTIMATION OF MOSQUITO SUITABILITY UNDER RCP 8.5 IN ETHIOPIA

MODEL CONSTRUCTION

Spatio-temporal distributions of *Anopheles gambiae* s.l. mosquitoes was determined using a raster-based suitability model constructed in Google Earth Engine by adapting methodology presented by Frake et al. [146] . This methodology uses abiotic variables specific to the thermal tolerances of vector species and biotic variables that give consideration to species habitat preferences. Suitable areas are defined as patches of landscape that facilitate the development of malaria mosquitoes through the production and persistence of oviposition sites and where temperatures do not exceed or fall below thermal tolerances. Parameter thresholds for all input variables were selected based on literature review of *An. gambiae* s.l. habitat: Temperature, Landcover, Precipitation, Flow Accumulation, and Water Resources (Table A1). Thresholds were then used to create binary maps for each predictor (i.e., suitable [1] or unsuitable [0]) that were combined using Boolean logic to produce suitability maps across three epochs, historical reference period (1986-2005), 2030-2049, and 2040-2059, during Ethiopia’s historic malaria transmission period: September-November. Population vulnerability was demonstrated by spatially overlaying suitability maps for malaria mosquitoes in Ethiopia with population data from the Global Human Settlement Layers (2015) to calculate the number of people residing in suitable areas, by region. Population data were held constant in all models in the absence of spatial population projection data. Output spatial resolution of products is 1000m: this analysis is performed at the landscape, not micro-scale level. Microscale variations in climatological and land use and land cover can and do affect species actual distributions.

TABLE A1.
Model parameterization and data sources for habitat characterization

INDICATOR	DATA SOURCE	PRODUCT	SPATIAL RESOLUTION	THRESHOLD
Temperature	NASA	NEX-GDDP	0.25 degrees	<i>An. gambiae</i> s.s. Min: 18°C Max: 34°C
Land Cover	Copernicus Global Land Service	Proba-V-C3	100 m	See Annex Table 2*
Water Resources	JRC	GSW1_0	30 m	>0 percent water occurrence
Flow Accumulation	WWF	HydroSHEDS	500 m	
Population	JRC	GHSL/P2016/POP_GPW_GLOBE_V1		

SUITABILITY DATA AND PARAMETERS

Temperature

Temperature is critical to mosquito development and life history. Temperatures that are either too low or too high can increase mortality in aquatic or adult stages. Bayoh and Lindsay [147] demonstrated that the upper and lower thresholds for *An. gambiae* s.s. aquatic development were 18°C and 34°C, respectively. Minimum and maximum temperature thresholds for this analysis were set to 18°C and 34°C. Data were acquired from the NASA NEX-GDDP at a 0.25 degree spatial resolution.

Land Use and Land Cover

There is a significant relationship between land use and land cover and the distribution of mosquito species with many species demonstrating strong preferences for specific land cover types. LULC data were acquired from the Copernicus Global Land Service Proba-V-c3 product. To determine whether classes were suitable for *An. gambiae* s.l. mosquitoes, class descriptions were compared to habitat preferences of the species according to literature review. *An. gambiae* mosquito habitats are characterized by open, sunlit pools which may be associated with human activity including agriculture which may facilitate water pooling. In this analysis, M-form and S-form *An. gambiae* s.s.(now known as *An. coluzzi* and *An. gambiae* s.s., respectively) mosquitoes habitat preferences were considered. *An. coluzzi* show preference for forested areas, greater sunlight exposure, higher water vapor pressure, and lower temperatures and evapotranspiration. S-forms prefer dry savannah and deciduous forest. To account for these species preferences, Proba class values, 20, 30, 40, 50, 60, 90, 111, 112, 113, 114, 115, 116, 121, 122, 123, 124, 125, and 126 were set to suitable (Table A2).

TABLE A2.

Copernicus Global Land Cover Layers: CG:S-LC100 Collection 2 global landcover map classifications.

CLASS VALUE	CLASS DESCRIPTION	SUITABLE <i>AN. GAMBIAE</i> S.L. LAND COVER
0	Unknown. No or not enough satellite data available.	No
20	Shrubs. Woody perennial plants with persistent and woody stems and without any defined main stem being less than 5 m tall. The shrub foliage can be either evergreen or deciduous.	Yes
30	Herbaceous vegetation. Plants without persistent stem or shoots above ground and lacking definite firm structure. Tree and shrub cover is less than 10 %.	Yes
40	Cultivated and managed vegetation / agriculture. Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.	Yes
50	Urban / built up. Land covered by buildings and other man-made structures.	Yes
60	Bare / sparse vegetation. Lands with exposed soil, sand, or rocks and never has more than 10 % vegetated cover during any time of the year.	Yes
70	Snow and ice. Lands under snow or ice cover throughout the year.	No

CLASS VALUE	CLASS DESCRIPTION	SUITABLE AN. GAMBIAE S.L. LAND COVER
80	Permanent water bodies. Lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies.	No
90	Herbaceous wetland. Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water.	Yes
100	Moss and lichen.	No
111	Closed forest, evergreen needle leaf. Tree canopy >70 %, almost all needle leaf trees remain green all year. Canopy is never without green foliage.	Yes
112	Closed forest, evergreen broad leaf. Tree canopy >70 %, almost all broadleaf trees remain green year round. Canopy is never without green foliage.	Yes
113	Closed forest, deciduous needle leaf. Tree canopy >70 %, consists of seasonal needle leaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Yes
114	Closed forest, deciduous broad leaf. Tree canopy >70 %, consists of seasonal broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Yes
115	Closed forest, mixed.	Yes
116	Closed forest, not matching any of the other definitions.	Yes
121	Open forest, evergreen needle leaf. Top layer- trees 15-70 % and second layer- mixed of shrubs and grassland, almost all needle leaf trees remain green all year. Canopy is never without green foliage.	Yes
122	Open forest, evergreen broad leaf. Top layer- trees 15-70 % and second layer- mixed of shrubs and grassland, almost all broadleaf trees remain green year round. Canopy is never without green foliage.	Yes
123	Open forest, deciduous needle leaf. Top layer- trees 15-70 % and second layer- mixed of shrubs and grassland, consists of seasonal needle leaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Yes
124	Open forest, deciduous broad leaf. Top layer- trees 15-70 % and second layer- mixed of shrubs and grassland, consists of seasonal broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Yes
125	Open forest, mixed.	Yes
126	Open forest, not matching any of the other definitions.	Yes
200	Oceans, seas. Can be either fresh or salt-water bodies.	No

Precipitation

Water is fundamental to mosquito larvae development. To estimate areas likely to become inundated annual average precipitation was calculated from the Climate Hazards Group InfraRed Precipitation and Station Data (CHIRPS v2.0). Likewise, flow accumulation was derived from HydroSHEDS Flow Accumulation product to determine the natural drainage from a given pixel to adjacent, downslope pixel to determine areas of inundation for larval oviposition sites. Finally, a water resources layer derived from the JRC Global Surface Water Bodies Mapping Layer v1.0 product was developed by buffering water bodies by 250-m to approximate water rich soils that would support larval development.

ANNEX F. OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION CHANGES IN ETHIOPIA

Observed (Reference Period 1991-2020) and Projected (2040-2059 Anomaly from 1995-2014 Baseline)
Temperature and Precipitation Changes in Ethiopia by Subnational Unit

CLIMATIC-TOPOGRAPHIC REGION (SUBNATIONAL UNIT)	OBSERVED WARMEST (TOP) AND COOLEST (BOTTOM) MONTH	OBSERVED WETTEST (TOP) AND DRIEST (BOTTOM) MONTH	PROJECTED ANOMALY (CHANGE) IN TEMP. AND PRECIP. CONDITIONS FOR 2040-2059	SEASON OF LARGEST PROJECTED CHANGE IN TEMP. AND PRECIP. CONDITIONS FOR 2040-2059
Tropical Dry (Kolla)	June (25C-38C)	Aug (96mm)	+35.07 (10.26, 53.09) Hot Days Annually	Spring Months
Northeast Rift Valley – Awash Valley, Denakil Depression (Afar)	Jan (18C-30C)	Dec (9mm)	+42.01 (10.73, 67.66) Trop. Nights Annually	Spring Months
		Annual (359mm)	+47.40mm (-155.17mm, 283.94mm) Seasonally	Summer Months (Kiremt)
Southeast Lowlands – Genale and Shebele Plains (Somali)	Apr (21C-33C)	Apr (102mm)	+64.95 (32.46, 97.46) Hot Days Annually	Spring Months
	Dec (17C-32C)	Jan (4mm)	+66.94 (30.50, 90.89) Trop. Nights Annually	Winter Months
		Annual (435mm)	+34.08mm (-135.83mm, 174.66mm) Seasonally	Fall Months (Kiremt)
Tropical Moist (Kolla Elevation)	Mar (23C-37C)	Aug (187mm)	+44.35 (-7.73, 84.88) Hot Days Annually	Fall Months
West Lowlands – Baro Lowlands (Gambela)		Jan (11mm)	+54.91 (4.87, 82.33) Trop. Nights Annually	Winter Months
	Aug (21C-31C)	Annual (1103mm)	+69.00mm (-223.68mm, 333.78mm) Seasonally	Fall Months (Kiremt)
Northwest Lowlands – Angereb Lowlands (Beneshangul Gumu)	Apr (21C-36C)	Aug (293mm)	+36.88 (11.14, 65.62) Hot Days Annually	Spring Months
	Aug (18C-28C)	Jan (1mm)	+71.42 (21.99, 105.03) Trop. Nights Annually	Summer Months
		Annual (1262mm)	+58.15mm (-172.63mm, 284.72mm) Seasonally	Fall Months (Kiremt)
Subtrop. Dry (Major Tigray Cities and Hareri in Weina Dega)	May (18C-32C)	Aug (187mm)	+25.06 (11.12, 45.66) Hot Days Annually	Spring Months
North Highlands – Tigrian Plateau (Tigray)	Jan (12C-28C)	Jan (3mm)	+36.16 (8.60, 62.00) Trop. Nights Annually	Spring Months
		Annual (601mm)	+26.48mm (-212.01mm, 346.78mm) Seasonally	Summer Months (Kiremt)
East Highlands – Hararghe Plateau (Dire Dawa)	June (22C-34C)	Aug (129mm)	+28.31 (8.03, 47.14) Hot Days Annually	Spring Months
	Dec (13C-29C)	Dec (8mm)	+19.11 (2.29, 62.66) Trop. Nights Annually	Spring Months
		Annual (640mm)	+34.57mm (-135.83mm, 168.30mm) Seasonally	Summer Months (Kiremt)

CLIMATIC-TOPOGRAPHIC REGION (SUBNATIONAL UNIT)	OBSERVED WARMEST (TOP) AND COOLEST (BOTTOM) MONTH	OBSERVED WETTEST (TOP) AND DRIEST (BOTTOM) MONTH	PROJECTED ANOMALY (CHANGE) IN TEMP. AND PRECIP. CONDITIONS FOR 2040-2059	SEASON OF LARGEST PROJECTED CHANGE IN TEMP. AND PRECIP. CONDITIONS FOR 2040-2059
East Highlands – Hararghe Plateau (Hareri)	June (17C-29C)	Aug (141mm)	+20.65 (8.35, 27.45) Summer Days Annually	Winter Months
	Dec (8C-27C)	Dec (10mm)	+14.40 (1.75, 32.00) Trop. Nights Annually	Spring Months
		Annual (829mm)	+30.49mm (-105.40mm, 131.67mm) Seasonally	Summer Months (Kiremt)
Subtrop. Moist (Major Cities in Weina Dega)	Apr (15C-30C)	Aug (307mm)	+38.80 (12.76, 63.37) Summer Days Annually	Fall Months
North Central Massif (Amhara)	Dec (10C-27C)	Dec (10mm)	+18.02 (2.41, 34.42) Trop. Nights Annually	Spring Months
		Annual (1138mm)	+51.36mm (-268.89mm, 417.37mm) Seasonally	Summer Months (Kiremt)
Southwest Lowlands and Highlands (SNNPR)	Mar (16C-31C)	May (152mm)	+32.44 (6.92, 53.83) Hot Days Annually	Spring Months
	Dec (13C-29C)	Jan (30mm)	+38.36 (6.03, 59.34) Trop. Nights Annually	Spring Months
		Annual (1165mm)	+29.93mm (-35.60mm, 153.53mm) Seasonally	Winter Months (Bega)
Subtrop. Moist and Temperate Moist (Mostly Weina Dega)	Apr (16C-29C)	Aug (159mm)	+34.02 (13.28, 52.54) Summer Days Annually	Fall Months
Central West, Central East Highlands – Shewa Plateau, Arsi-Sidama-Bale Massif (Oromia)	Dec (12C-27C)	Dec (18mm)	+25.76 (7.53, 43.56) Trop. Nights Annually	Spring Months
		Annual (1105mm)	+37.11mm (-152.74mm, 260.07mm) Seasonally	Fall Months (Kiremt)
Temperate Moist (Weina Dega)	Apr (12C-26C)	Aug (275mm)	+62.45 (29.22, 93.62) Summer Days Annually	Fall Months
Central Highlands – Shewa Plateau (Addis Ababa)	Dec (7C-24C)	Dec (9mm)	+0.00 (0.00, 0.11) Trop. Nights Annually	--
		Annual (1161mm)	+37.97mm (-116.06mm, 188.09mm) Seasonally	Spring Months (Belg)

Note: Temperature ranges in parentheses for the warmest and coolest months indicate the average minimum and maximum for 1991-2020. This reference period also applies to the annual and monthly observed precipitation amounts. Projected midcentury temperature and precipitation anomalies correspond with the SSP3-7.0 ensemble and 1995-2014 reference period. Parentheses indicate 10th and 90th percentile values, respectively. “Hot Days Annually” have maximum daily temperatures >35°C, “Tropical Nights Annually” have minimum daily temperatures >20°C, “Summer Days Annually” have daily maximum temperatures >25°C, and precipitation anomalies correspond with the largest projected volume seasonally, not annually, indicated in the far-right column. Red bolded values indicate notable outliers or relative extremes.



JANUARY 2024

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