Situational Analysis and Needs Assessment for Ethiopia

AIR POLLUTION, OCCUPATIONAL HEALTH AND SAFETY, AND CLIMATE CHANGE

FINDINGS, RESEARCH NEEDS AND POLICY IMPLICATIONS

Establishing a GEOHealth Hub for East Africa

School of Public Health, Addis Ababa University, Ethiopia

&

University of Southern California, USA

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Abera Kumie, Jonathan Samet and Kiros Berhane
Section III

Situational Analysis and Needs Assessment:

CLIMATE CHANGE AND HEALTH IN ETHIOPIA

Establishing a GEOHealth Hub for East Africa
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Summary

Background

Climate change is recognized to have a potentially severe impact on public health in the African Region, especially East Africa. Ethiopia has been identified as one of the countries vulnerable to the effects of climate change, primarily due to population pressure, poverty, a fragile ecosystem, and the country’s reliance on a climate-sensitive economy. Climate change-related health problems, such as mortality and morbidity due to floods and heat waves, vector-borne diseases, water-borne diseases, meningitis, and air pollution-related respiratory diseases are increasing. Efforts to mitigate and adapt to the impacts of climate change are being undertaken by various sectors but are lacking coordination. Moreover, there have been limited trained personnel, laboratories and other facilities to support climate-related research. Taking these facts into consideration, the aim of the Situational Analysis and Needs Assessment (SANA) on climate change and health was to assess the country’s existing situation on issues related to the environment, climate change, and occupational health, and to identify gaps and needs for which research, training, and capacity-building projects can be developed in Ethiopia and other East African countries.

Methods

This SANA assessment was carried out by conducting a comprehensive review of available secondary data and interviewing key informants in various national organizations involved in climate change adaptation and mitigation activities. Published documents were searched using select online keywords, while secondary data from hard copies of various policy and program documents were extracted. Semi-structured questions (checklists) were used to interview key informants in various organizations who were responsible for managing and overseeing the climate-related activities.

Findings

Information obtained both in the situational analysis and needs assessment revealed that climate change currently represents one of the greatest development challenges in Ethiopia. Sensitive systems such as agriculture, health, and water have been affected, and the effects of climate change will continue to magnify without the right adaptation and mitigation measures. The current stage of research on climate change and health is rudimentary; research findings and other activities tend to appear largely fragmented and uncoordinated. As a result, there are few spatially detailed, methodologically consistent climate impact studies available for the country.

In Ethiopia, there have been repeated drought, floods, malnutrition, extreme temperature events (extreme heat and cold), and re-emergence of climate-sensitive diseases. Increased environmental survival of pathogens and creation of new ecological niches for vectors to propagate diseases are also observed. While the impact of climate change on health and other related issues is recognized by various governmental stakeholders, the specific actions and responses have little oversight.
This assessment identified the existence of poor collaboration between different organizations on planning and executing activities related to climate change and health, and a lack of trained professionals who can independently perform climate change and health-related research and activities at various levels. The SANA also revealed a lack of well-organized structure in the various organizations and poor inter-sectoral collaboration; poor coordination and communication among different stakeholders; lack of policies and programs that independently target climate change and health; inability of the existing policies to consider the gender and community dimensions of climate change; and weak monitoring and evaluation efforts on climate change and health activities at various organizations.

Conclusion

With the understanding of the current status, we suggest that additional and well-targeted efforts need to be in place to halt the current weak multidimensional climate change induced problems through organized community, professional, and organizational collaboration and networking.

Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAU</td>
<td>Addis Ababa University</td>
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<td>ACCRA</td>
<td>African Climate Change Resilience Alliance</td>
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<td>APP</td>
<td>Adaptation Program Plan</td>
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<td>AWD</td>
<td>Acute Watery Diarrhea</td>
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<td>CCF</td>
<td>Climate Change Forum</td>
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<td>CFR</td>
<td>Case Fatality Rate</td>
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<td>CGE</td>
<td>Computable General Equilibrium</td>
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<td>CO₂</td>
<td>Carbon Dioxide</td>
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<td>CRGE</td>
<td>Climate Resilient Green Economy</td>
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<td>CRGEvision</td>
<td>Climate Resilient Green Economy Vision</td>
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<td>CSA</td>
<td>Central Statistical Agency</td>
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<td>CSE</td>
<td>Conservation Strategy of Ethiopia</td>
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<td>DDAEPA</td>
<td>DreDawa Administration Environmental Protection Agency</td>
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<td>DRMFSS</td>
<td>Disaster Reduction Management Food Security Sector</td>
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<td>EC</td>
<td>Environment Council</td>
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<td>ECPA</td>
<td>Ethiopian Consumers Protection Association</td>
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<td>EDHS</td>
<td>Ethiopian Demographic and Health Survey</td>
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<td>EDRI</td>
<td>Ethiopian Development Research Institute</td>
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<td>EIAR</td>
<td>Ethiopian Institute of Agricultural Research</td>
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<td>Acronym</td>
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<tr>
<td>EPACC</td>
<td>Ethiopian Program of Adaptation to Climate Change</td>
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<td>EPE</td>
<td>The Environment Policies of Ethiopia</td>
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<td>EPA</td>
<td>Environmental Protection Authority (Ethiopia)</td>
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<td>FDRE</td>
<td>Federal Democratic Republic of Ethiopia</td>
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<td>FfE</td>
<td>Forum for Environment</td>
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<td>FMOH</td>
<td>Federal Ministry of Health</td>
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<td>GCM</td>
<td>Global Climate Models</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GEOHealth</td>
<td>Global Environmental and Occupational Health</td>
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<td>GoE</td>
<td>Government of Ethiopia</td>
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<td>GTP</td>
<td>Growth and Transformation Plan</td>
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<td>IMF</td>
<td>International Monetary Fund</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>LDC</td>
<td>Less developed countries</td>
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<td>LEAP software</td>
<td>Livelihoods, Early Assessment and Protection' software platform</td>
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<td>MDG</td>
<td>Millennium Development Goals</td>
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<td>MIS</td>
<td>Management Information System</td>
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<td>MOA</td>
<td>Ministry of Agriculture</td>
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<td>MOWE</td>
<td>Ministry of Water and Energy</td>
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<td>NAMAs</td>
<td>Nationally Appropriate Mitigation Actions</td>
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<td>National Adaptation Programs of Action</td>
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<td>National Acute Watery Diarrhea Prevention and Control</td>
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<td>NGOs</td>
<td>Non Governmental Organizations</td>
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<td>NMA</td>
<td>National Meteorology Agency</td>
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<td>PASDEP</td>
<td>Plan for Accelerated and Sustainable Development to End Poverty</td>
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<td>PSNP</td>
<td>Productive Safety Net Programme</td>
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<td>RDPS</td>
<td>Agricultural and Rural Development Policy Strategies</td>
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<td>SANA</td>
<td>Situation Analysis and Need Assessment</td>
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<td>SLMP</td>
<td>Sustainable Land Management Program</td>
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<tr>
<td>UNDP</td>
<td>United Nations Development Program</td>
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<td>UNFCCC</td>
<td>United Nation Framework Convention on Climate Change</td>
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<td>WB</td>
<td>World Bank</td>
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<td>WFP</td>
<td>World Food Program</td>
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Introduction

Climate change and health

The global climate is changing due to the carbon-intensive paths of development that have been pursued by high-resource countries since the beginning of the industrial revolution. During the past century, the size of the human population and its impact on the environment have increased dramatically. The emission of greenhouse gases, especially the release of carbon dioxide (CO₂) into the lower atmosphere, have increased from a pre-industrial value of about 280 ppm to 400 ppm in 2010 (1). The concentration of CO₂ in the atmosphere has increased by nearly 30% and most of the CO₂ released each year has been contributed disproportionately by the United States, Canada, Australia, the countries of Europe, and, more recently, China (1).

During the last century, the world’s average surface temperature increased by approximately 0.8°C, and about two-thirds of that warming has occurred since the 1970s (2, 3). The Third Assessment Report (4) of the Intergovernmental Panel on Climate Change (IPCC) projected an increase ranging from 1.4 to 5.8°C in average world surface temperature over the course of the twenty-first century, absent effective intervention. Accumulation of greenhouse gases such as CO₂ in the lower atmosphere has contributed to the recent uptrend in world average temperature. The IPCC report also revealed that most of the warming observed over the last 50 years is attributable to human activities.

Climate change and health in Ethiopia

Climate change has been recognized as having a severe impact on public health in the African Region. Despite their insignificant contributions to the emissions of CO₂, countries in Africa including Ethiopia are disproportionately affected by the harmful effects of climate change. The African ecosystem is further characterized by poor physical infrastructure, fragile environments, dominance of climate-sensitive industries such as horticulture, and low adaptive capacity to climate change (4). The impacts of climate change usually occur as a result of anomalies in temperature and rainfall. The major health effects include under-nutrition due to variability in agricultural production and food security; increasing incidence of climate sensitive diseases such as malaria, meningitis, and diarrhea; and other adverse health impacts due to scarcity of water and natural disasters such as floods and droughts.

Climate change is of critical importance to Africa and in particular Ethiopia. Human-induced climate change will bring further warming over the next century at unprecedented rates. Climate models suggest that Ethiopia will see further warming in all seasons between 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s (5). Ethiopia has a total population of 74 million (6)(CSA 2007) that grows annually by 2.6% and is expected to more than double by 2050. Agriculture is the backbone of the country’s economy, engaging more than 85% of the total population. The country is extremely vulnerable to the impacts of climate change, which could potentially hold back economic progress or reverse the gains made in development and thus exacerbate social and economic challenges.

Ethiopia has been identified as one of the countries in the world most vulnerable to the adverse effects of climate change (4). The country’s vulnerability to climate change is further increased by high levels of
poverty, rapid population growth, reliance on rain-fed agriculture, high levels of environmental degradation, chronic food insecurity, frequent natural drought cycles, poor infrastructure in drought-stricken areas, and low adaptive capacity. Recurrent droughts and floods have resulted in loss of life and property as well as displacement of people. Drought frequency is predicted to increase, placing stress on already vulnerable food production systems. Climate change is expected to bring fiercer competition for water and other resources.

**Climate-Resilient Green Economy**

In view of this vulnerability and its consequences, Ethiopia has committed to building a Climate-Resilient Green Economy (CRGE) to ensure economic development that pursues a low-emissions path while building resilience to climate change (7). The Government of Ethiopia (GoE) has recognized the need to capitalize on opportunities created by climate change to realize these goals through partnerships with international institutions. Thus, the GoE’s green economy strategy targets seizing the financial opportunities and sustainability co-benefits of low emissions development, while its climate-resilient development strategy focuses on managing risk and building resilience to shocks through sequenced measures (7).

The aim of the Global Environmental and Occupational Health (GEOHealth) Situational Analysis and Needs Assessment (SANA) project in Ethiopia is to evaluate the country’s existing situation in issues related to the environment, climate change, and occupational health, and to identify gaps and needs for which research, training, and capacity building projects can be developed in Ethiopia and other East African countries.

**Methods**

Before the commencement of information gathering from various sources, the AAU based Principal Investigator and other senior co-investigators provided an orientation to team members who were selected to assist in project research. Keywords for literature reviews and semi-structured questions were prepared and agreed upon among the AAU and USC based investigators.

An extensive literature search of published documents with a focus on Ethiopia was conducted online using keywords such as ‘impact of climate change’, ‘health’, ‘economy’, ‘water-borne disease’, and ‘vector-borne disease’. In addition, relevant policy and program documents published in hardcopy by various key stakeholders were reviewed.

Semi-structured questions (checklists) were used to interview key informants who were responsible for managing and overseeing climate-related activities in various organizations including the MOWE, MOH, MOH-PHEM, MOA, MOA-DRMFSS, and NMA. This step was taken to obtain primary data aimed at understanding the gaps and needs of each institution with regard to climate change and health-related capacity.
Assessment Findings: Situational analysis on Climate Change and Health

The state of climate in Ethiopia

Ethiopia’s First National Communication (8) analyzed historical temperature and precipitation data from 1961 to 1990, and identified high spatial and temporal variability: a more or less constant average annual precipitation at the national scale, but with declining trends in the northern areas and increasing trends in the central parts of the country. The study also found that Ethiopia has experienced both dry and wet years and a warming trend in temperature over the last 50 years.

Rainfall variability

In addition to high inter-annual rainfall variability in Ethiopia, some researchers have reported that rainfall has recently exhibited a downward trend in parts of the country. This situation, however, is non-uniform and varies by the region or period of time used for analysis. For example, FEWS (9) reported a significant decreasing trend of rainfall during the rainy season (Kiremt) in the southwestern highlands of the country for the period 1961-1996. Conway (2000) reported absence of any long-term trend for annual rainfall in the northern and north-eastern parts of the country. Conway and colleagues (10) analyzed the 104-year rainfall record of Addis Ababa in the central Ethiopian highlands and found no upward or downward trend over the period 1898-2002. This pattern was supported by (11) who found no significant trend in the annual and seasonal rainfall totals in the central, northern, and north-western parts of the country over the period 1965-2002. Seleshi and Zanke (2004)(11), however, did find significant declines in the annual and kiremt rainfall totals in the eastern, southern, and southwestern parts of Ethiopia. Meze-Hausken (12) also reported absence of a declining trend in rainfall in the northern and north-eastern areas of Ethiopia, despite local people’s perceptions that the total rainfall had decreased over the past 25-30 years because of the loss of spring rains (March-May, belg) and a shortened kiremt. Bewket and Conway (13) analyzed rainfall in the Amhara region and found that during the 1990s it had recovered from a dry phase in the 1980s, although rainfall levels in 2001-2003 were average or slightly lower than average. Rainfall in the central and northern highlands has recovered substantially since the 1980s, with intermittent dry years.

A detailed study of Ethiopian rainfall trends by Funk et al. (14) identified some notable features, as summarized in Figure 1.
Multiple sources of evidence converge on a post-1997 tendency towards lower rainfall, especially during the Belg (March-May) season. This finding appears to hold for many parts of eastern Africa.' Positive temperature anomalies in the southwestern Indian Ocean may increase oceanic precipitation and decrease rainfall over eastern Africa, especially during March-May. If rapid warming (about 1°C in the last 50 years) of the Indian Ocean is related to reduced rainfall over eastern and southern Africa, then continuing rainfall deficits may be likely (14).

**Changes in the frequency of extreme events**

Ethiopia has been experiencing climate extremes, such as droughts and floods, increasing temperature, and erratic rainfall (15). Studies show that the frequency and magnitude of droughts has increased over the past few decades, especially in the lowland areas of the country (16). Drought occurrences are becoming endemic to Ethiopia (Figure 2) and are severely affecting the livelihoods of millions of people. According to the 2010 World Bank report, Ethiopia has been affected by frequent severe droughts since the early 1980s—five of which have led to famines—in addition to dozens of local droughts (17). Severe droughts resulted in the drying of water sources, leading to serious water shortages, especially in the lowland ecosystems of Dire.dawa. This compromised personal hygiene resulting in escalated faeco-oral transmission of diseases (18).
Many areas of the country are prone to flooding, which is the second most important natural disaster; its increasing occurrence adds more stress to local governments’ spending and increases the vulnerability of households in Ethiopia (Figure 3). The major floods that occurred in 1988, between 1993-1996, and in 2006 resulted in considerable loss of life and property (15).

A recent study by Abaya and colleagues assessed the flood risks and health-related issues in the Gambella region of the country. This study identified three critically important weaknesses including lack of flood-specific policy, absence of risk assessment, and weak institutional capacity(20). The 2008 Gambella flooding was one example of the increased frequency and magnitude of flooding in other parts of the country over the past decade. Nevertheless, the floods in Gambella were attributed to land-use changes (deforestation and over cultivation) as well as climate change. The presence of rivers such as Baro, Akobo, Gilo, and Alwero and low lying homogeneous topography were also contributing factors to the floods in the area.
In the Afar region, climate-related risks such as drought and floods have always posed problems to human health. The region has one of the highest child mortality rates in the country, and the number of people suffering due to heat waves has been rising (21). The problem is aggravated by the inadequacy of medical facilities and qualified and trained local personnel (21).

Another report indicated that drought, erratic rainfall, animal diseases, shortage of water, and human diseases induced by climate change were the major hazards in Chifra wereda of the Afar Region (22). Trends are evident not only for increasing temperatures and declining short rains, but also for population growth, rangeland degradation, significantly decreased herd size per household, increase in basic infrastructure and incentives for settlement (22). The same report also found that there have been increasing temperatures, shortening rainfall, population growth, deforestation, shrinking plot sizes, and decreased availability of grazing land in the Gemechis district of Oromia Region (22).

In the Borana and Somali communities of Ethiopia, increased human health problems are already present due to high temperatures, increased dust from stronger winds over barren lands, and drinking water scarcity. Most of the natural, financial, human, and social resources on which Borana and Shinile communities depend are already significantly affected by climate-related hazards (23). Higher temperatures and increased rainfall intensity may lead to flash floods that result in more water-borne diseases in Borana, while hotter and dryer seasons in Shinile could change the distribution, range, prevalence, incidence, and seasonality of sanitation-related and vector-transmitted diseases (23).

Floods also damage crops and inundate farmland, resulting in food shortages that may lead to malnutrition. For instance, the 2006 flood in the Gambella region caused damage to 1,650 ha of maize crops (20). According to local reports, production was reduced by 20%, mainly due to waterlogging on the farmlands. Most people affected by this flood were very poor and were considered highly vulnerable with regard to food security. Though it is difficult to relate flooding to nutritional status without comparison to prior surveys, it is very likely that shortages of food caused by flooding exacerbate existing malnutrition in the country.

**Local experiences of climate variability and change**

Some published studies reported that Ethiopians have perceived changes in local climatic conditions. For example, a survey of 1000 households in the Blue Nile Basin found roughly 68% of respondents perceived an increase in mean temperature during the last 20 years, with just 4% reporting a perceived decrease and 28% reporting unchanged temperature (24). For mean annual rainfall, 18% of respondents perceived an increase, 62% a decrease, and 20% no change. Roughly 58% and 42% of people had not adopted adaptation measures in response to long-term shifts in temperature and precipitation, respectively. Reasons for lack of adoption included lack of information (main reason), as well as shortages of labor, land, and money (24).

Village surveys conducted for a World Bank study on cost of adaptation noted that in several focus group discussions, participants indicated that the quantity and periodicity of rainfall had changed over...
the past decades (25). Experiences varied between the highland, midland, and lowland areas. The spring (belg) rains were noted to be almost disappearing from the highlands, especially during the previous five years, and the report quoted one highlander as saying: “Before, we used to produce twice during the year but these days we are not seeing belg rains regularly; and the quantity of kiremt rains that we are getting in the past five years does not even amount to the belg rains that we used to get like ten years ago’. Farmers from the midland and lowland areas indicated that they had been affected by lower rainfall and higher variability at the onset of the rainy season. In all areas, the start and finish of the rainy seasons were found to be more irregular (25).

Climate model projections for Ethiopia

Global climate models (GCM) provide the most reliable sources of information on the characteristics of future climate change. The results of GCM experiments to simulate future response of the climate system to increasing concentration of greenhouse gases globally are generally referred to as scenarios. Scenarios often comprise changes in temperature, rainfall, some other climate variables, and limited information about changes in extremes. It is important to present results from several GCMs to account for the range of possible changes that could occur due to differences in the rate of emissions of greenhouse gases and differences between GCM simulations of the behavior of the climate system.

McSweeney et al. (26), using 15 GCMs (an ‘ensemble’), averaged them to provide a guide to the overall direction of changes across all models, while values from the warmest/coolest and wettest/driest models were used to illustrate the range of uncertainty in the scenarios. The study concluded that all scenarios showed continued warming throughout Ethiopia accompanied by complex patterns of rainfall change, with considerable differences between GCMs. Higher rates of emissions produce faster rates of warming, while the warming itself is associated with greater frequency of heat wave events. Higher temperatures are likely to lead to higher rates of evaporation and, assuming other influences remain unchanged, higher rates of surface water evaporation and higher soil moisture deficits.

The magnitude (and trend) of climate-sensitive diseases

According to the Ethiopian Climate Resilient Green Economy document (7), the health impacts of climate change will be apparent in six mechanisms:

- morbidity and mortality through temperature extremes;
- increases in vector-borne diseases, such as malaria and bilharzia;
- increases in non-vector-borne diseases related to weather conditions (for example, diarrheal disease and cholera associated with both floods and drought);
- health problems associated with weather-related air quality;
- injury and mortality through floods and storms;
- impacts of climate-related influences on food and water supply (for example, malnutrition).

According to an estimate by McMichael and colleagues, about 36,000 lives were lost each year across Eastern Africa (including Ethiopia) because of climate change (27). The 4th IPCC report calculates that
the greatest future health risks associated with climate change in 2030 will be flooding, followed by malaria, diarrheal disease, malnutrition, and cardiovascular diseases (2)

Vector-borne diseases

Changes in climate are likely to lengthen the transmission period of major vector-borne diseases and to alter their geographic range. Studies have suggested that climate change could expose an additional 2 billion people to dengue transmission by the 2080s (28). Climate change is projected to significantly widen the area where the snail-borne disease schistosomiasis occurs (29). The 4th report of the IPCC stated that by the 2050s malaria will have entered into the highland areas of Ethiopia and that by 2080 conditions will be highly suitable for malaria transmission (2).

The National Adaptation Programs of Action (NAPA) also reported that climate change is projected to cause encroachment of malaria from lower altitudes in the Somalia and Afar regions to higher altitudes in Tigray and Amhara (15). In 1990 it was estimated that 6,508, 530 people, in areas of Ethiopia where the climate is more than 75% suitable for proliferation of malaria-transmitting mosquitoes, were at risk for endemic malaria. Several reports found that an increase in global mean temperature has created conducive ecological conditions for vector breeding and spreading of vector-borne diseases such as malaria. Limited research currently available on Ethiopia indicated that a positive association exists between climatic variability and infectious diseases such as malaria. Malaria is seasonal and unstable in Ethiopia, with the peak malaria transmission season ranging from September to December and coinciding with the major crop-harvesting season; thus, economic losses could be aggravated. Malaria is the top leading cause of outpatient visits, accounting for 12% of the total outpatient morbidity in 2007-2008 (30). It poses a significant economic burden on rural households and individuals both through increased out-of-pocket payments and person-days lost (31).

Using parasite survey data in conjunction with one climate model, Tanser and colleagues (32) estimated a 5-7% potential increase (mainly altitudinal) in malaria distribution. They also found that malaria-free highland areas in Ethiopia, Kenya, Rwanda, and Burundi could experience modest changes to malarial conditions by the 2050s, with conditions for transmission becoming highly suitable by the 2080s.

The 2007 MIS report estimated that parasite prevalence in Ethiopia as measured by microscopy was 0.7% and 0.3%, for P. falciparum and P. vivax, respectively, in regions below 2,000 meters altitude. The MIS 2011 draft report showed that 1.3% of children under age of 5 years tested positive for malaria using microscopy and 4.5% tested positive using rapid diagnostic tests. P. falciparum accounted for 77% of these infections. The 2011 MIS survey demonstrated a remarkable demarcation of malaria risk at an altitude of 2,000 meters, with thirteen-fold higher malaria prevalence at lower altitudes compared to higher elevations. Essentially no P. falciparum was detected by microscopy among persons surveyed within households with measured elevations above 2,000 meters in the MIS 2011 report (33).
According to the World Health Organization, 68% of Ethiopians are already living in areas at risk for malaria, where transmission is unstable and characterized by large-scale epidemics (17). For example, in 2003 large-scale epidemics resulted in 2 million confirmed malaria cases and 3000 deaths.

Based on an analysis using malaria morbidity data from the late 1980s until the early 1990s from 50 sites across Ethiopia, malaria epidemics were associated with high minimum temperatures in the preceding months (34). A more recent study in Jimma found that during the previous ten years (2000-2009), a fluctuating trend of malaria transmission was observed, with *P. vivax* becoming the predominant species (35). Monthly minimum and maximum temperatures and monthly total rainfall, at one month lagged effect, were significant meteorological factors for transmission of malaria in the study area (35).

A study in southern Ethiopia showed that *P. falciparum* malaria incidence models were linked to meteorological data while the observed variability in the models was principally attributed to regional differences, and no single model was found to fit all locations (36).

The 2010 WHO Ethiopia Country office reported that due to population movement, immune suppression (due to HIV/AIDS, malnutrition, etc.), and climate changes, the Leishmaniasis disease was observed to have spread to new localities in Ethiopia over the previous 5 years, including Libo and Fogera in Amhara, Tahtay Adiabo in Tigray, and Imey in Somali regional states (37).

A study in Boricha, Sidama found a positive association between malaria incidence and temperature in March, May, and the months between July and October; and between malaria incidence and rainfall from January to April and in the months of September and November. There was also a pattern of dramatic decrease and increase in malaria cases before and after the peak rainy season in May, respectively (38).

Climate change-induced malaria has also been reported in the Afar region (21). In South Omo, the rate of flooding has also increased and a large area has come under permanent flooding, triggering the infestation of bush and mosquitoes (malaria) (39).

**Soil-transmitted Helminthiases (STHs) STOPPED HERE**

After malaria, soil-transmitted helminthiases (STHs) account for the highest burden of parasitic disease worldwide (40). Most of Ethiopia already has conditions suitable for the transmission of STHs, and as a result the country has the third largest hookworm-infested population in sub-Saharan Africa, the second largest population infected with ascariasis, and the fourth largest population infected with Trichuriasis (41). A large number of those affected are children. These parasites can cause abdominal pain, gastrointestinal problems, and anemia, and can also hinder growth in children (42). In addition, these parasites can increase the risk of other diseases, including HIV/AIDS, malaria and tuberculosis (40).

Because STHs require specific climatic conditions to thrive, climate change could have a significant influence on their abundance and distribution. Soil temperature, humidity, and precipitation all effect the...
biological development of the STHs. Weaver at al. described STHs’ fluctuations around endemic areas as well as transmission to new regions (40).

**Water-borne diseases in general**

Increasingly variable rainfall patterns are likely to affect the supply of fresh water. Lack of safe water can compromise hygiene and increase the risk of diarrheal disease, which kills 2.2 million people every year globally. In extreme cases, water scarcity leads to drought and famine. By the 2090s, climate change is likely to widen the area affected by drought, double the frequency of extreme droughts, and increase their average duration six-fold (43). Floods are also increasing in frequency and intensity. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drowning and physical injuries, damage homes, and disrupt the supply of medical and health services (44).

Numerous researchers found that temperature, precipitation, and humidity have been among the most important determinants for diarrheal disease in different parts of the world (45-48). Increased ambient temperatures are often correlated with waterborne disease outbreaks (46, 49). Pathogens that cause water-borne diseases are generally temperature-dependent, whereby rising water temperatures result in increased growth of bacteria in water (50), leading to increased rates of diarrheal diseases (51).

Climate change-induced flooding results in the disruption of drinking water sources and pollution, leading to outbreaks of water-borne diseases, especially diarrhea (52). Floods transport pathogens into drinking water sources, increasing the risk of exposure to these water-borne pathogens. Seasonal variation of water quality has been described in various studies (52, 53) and the concentration of parasites was found to be significantly higher in water samples taken following heavy rainfall (54).

In another context, declining rainfall and accelerated evaporation may reduce runoff, threatening the availability of fresh water for human and industrial consumption. Drought conditions can concentrate contaminants in smaller volumes of water and affect hygiene practices that control the spread of infectious diseases (55). The decrease in rainfall amount will be exacerbated by higher evaporation rates associated with increasing temperatures (55). In several studies, maximum temperature and extreme rainfall days were strongly related to diarrhea-associated morbidity (56, 57). A strong association was also observed between daily mean temperature and precipitation with the incidence of hospitalization due to acute diarrhea in Thailand, resulting in a distinct spatial pattern in the seasonal pattern of diarrhea in that country (58). The impact of these changes has been significant among children (59, 60).

**Water-borne diseases in Ethiopia**

Few studies have examined the association between climate change and water-borne disease at the local level in Ethiopia. However, the available reports indicate possible linkage. Based on the recent EDHS, diarrhea has been most common among children age 6–23 months, and the prevalence was highest among children residing in households that drink from unprotected wells and those residing in...
rural areas (EDHS, 2011). Thirteen percent of children under age five years were reported to have had diarrhea, and 3 percent had diarrhea with blood in the two-week period before the survey. Moreover, the prevalence of diarrhea varies seasonally (EDHS, 2011). An epidemic of cholera following extreme floods in 2006 led to widespread illness and loss of life (61).

There have been reports from nine regions and two city administrations of acute watery diarrhea (AWD) from some affected areas of Ethiopia since April 2006 at different times. In 2006, a total of 51,201 cases and 558 deaths (CFR 1.1%) were reported from 146 woredas in 8 regions. The outbreak continued in 2007 and affected 317 woredas in all regions and city administrations. During this period, 49,511 cases and 775 deaths (CFR 1.3%) were reported. Similarly, in 2008 and 2009 a total of 3,870 cases and 23 deaths (0.6%), and 31,509 cases and 434 deaths (1.38%) were reported from 55 and 130 woredas, respectively. These outbreaks were linked to lack of basic sanitation and safe water supply in the locality of investment farms and religious gathering places, as well as to the high sensitivity of diarrheal pathogens to variations in climatic variability (62). In addition, prevention and treatment strategies for water-borne disease are not well established and therefore, climate change is likely to greatly impact the already poor efficacy of the strategies (63).

The FMoH understands that AWD is not only a health problem but also a challenge to overall development. This burden is further exacerbated by an unclean water supply, inadequate sanitation, and poor hygiene practices of many. However, the response to this burden was unsatisfactory because of the lack of a control strategy (62).

With this understanding the FMoH has developed the AWD Prevention and Control Strategy, with the goal of an AWD-free Ethiopia by the end of 2015. The general objective of the program is twofold: 1) to prevent and control AWD occurrence through comprehensive preventive and promotional approaches to protect citizens from the consequences of AWD; and 2) to contribute to the promotion of sustainable growth and transformation of the country with strategies of coordination and collaboration, health promotion and communication, prevention activities, case managements, public health surveillance, emergency preparedness, response and recovery, capacity building, and the implementation framework of the program (62).

**Zoonotic diseases in general**

Climate and environmental change could be associated with many emerging and re-emerging zoonoses that can be transmitted from animals to humans and from humans to animals, and may be acquired or spread through the air, by direct contact, by contact with an inanimate object that harbors the disease, by oral ingestion, and by insect transmission (64). An estimated 75% of emerging infectious diseases in humans have evolved from exposure to zoonotic pathogens (65, 66). These emerging diseases are new infections resulting from the evolution or change of an existing pathogen or parasite resulting in a change of host range, vector, pathogenicity or strain, or the occurrence of a previously unrecognized infection or disease.
Climate change may also cause an increased risk of food contamination, increased environmental survival of pathogens, changes in prevalence of pathogens in animal reservoirs, and changes in host–parasite ecology, which may enhance the risk of food borne disease (67). It could also potentially shift boundaries for spatial distributions, host–parasite assemblages, demographic rates, life-cycle phenologies, associations within ecosystems, virulence, and patterns of infection and disease (68). For example, an increase of a few degrees in environmental temperatures may lead to marked increases in cercarial emergence from snails (69).

Climatic variation also creates new ecological niches for vectors, hence altering temporal and spatial distribution of disease (70). It also influences the epidemiology of zoonotic diseases primarily by inducing changes in reservoir and vector dynamics (71). Therefore, any changes in the ecological conditions influencing wildlife diseases are also likely to have potential direct impact on human health (72).

Zoonotic infections are on the rise and pose significant additional threats to human health (73), where the problem is worsened due to the complexity of the different organisms involved, the difficulties posed by the numerous and changing biotic and abiotic factors influencing their epidemiology and transmission, and the huge challenges they pose for control (74). According to the report compiled by Grace and Jones (75) in low-income countries zoonoses or diseases recently emerged from animals are responsible for one-fifth of infectious diseases, contributing to the burden of human sickness and death (75).

**Zoonotic diseases in Ethiopia**

In a meta-analysis of zoonotic diseases worldwide, Grace et al. looked at 56 major zoonoses and determined that these diseases account for 2.7 million deaths and 2.5 billion cases of sickness each year (42). Ethiopia was identified as a "hotspot" for zoonotic disease events and was ranked as the number one hotspot for leptospirosis, fourth greatest hotspot for Q fever and Trypanosomosis, and tenth for tuberculosis (42). The same author assessed the global burden of disease for zoonoses and determined that 68% of the burden is distributed among only 13 countries, with Ethiopia having the 4th highest burden (42). These data indicate an already existing burden of zoonotic disease in the country, and this burden has the potential to be exacerbated by the effects of climate change.

Although only a limited number of studies have examined the effect of climate change and zoonotic disease in Ethiopia, the current existing conditions seem suitable for the occurrence of climate-induced zoonotic disease. In an attempt to assess the burden of leptospirosis in Ethiopia, Yimer et al. conducted a pilot study in Wonji hospitals to test patients for the condition and found that almost half of all patients tested for leptospirosis were positive for the illness (76). Researchers have identified an association between outbreaks of leptospirosis and extreme rainfall and flooding in a wide range of countries with different ecologies (77). Transmission of leptospirosis can occur through direct exposure to infected livestock, contamination of water sources from flooding, and/or poor sanitation conditions. Additionally, higher temperatures are linked to increased incidence of the condition (77). Ethiopia's large livestock population, in conjunction with predicted increases in both temperature and flooding and an established
burden of disease, suggests that climate change may greatly increase incidences of leptospirosis in the country.

In addition to the changing climatic variability, there has been rapid deforestation and degradation of land resources, mainly due to population increases in Ethiopia. This affects the ecological niches of various diseases which favor their transmission and leads to environmental changes that can contribute to transmission of waterborne diseases through grazing lands (78). The country’s forest areas have been reduced from 40% a century ago to an estimated less than 3% today (79). Ethiopia possesses one of the largest livestock populations on the African continent (80) and 90% of rural households own farm animals (81). Sharing of the house with animals is common (80) and can expose inhabitants to various zoonotic diseases.

Since the consequences of climate change have strong associations with poverty and social inequality, its impacts will be felt in different ways and severities by different communities and social groups in Ethiopia. It is well recognized that the most vulnerable and marginalized communities and groups are those who will experience the greatest impacts (4), and are in the greatest need of support and adaptation strategies. At the same time, it is the vulnerable and marginalized who lack, or have the least access to, information, technology, or opportunity to adapt to current climate variability and sufficiently prepare for future changes in the climate system. More specifically, climate change poses a significant challenge to the reduction of poverty and social inequality for the rural poor, especially women, the marginalized, the disabled, and those living with HIV/AIDS, who will suffer disproportionately from its multifaceted and growing impacts.

Meningitis in general

Meningococcal infection has been recognized as a serious public health problem for almost 200 years worldwide, and over 80% of bacterial meningitis can be traced to three disease causing agents: Neisseria meningitides, Streptococcus pneumonia, and Hemophilus influenzae Type B. The disease can occur as a sporadic case, an institution-based focal outbreak, or a large epidemic year (82). Without treatment, bacterial meningitis kills up to 50% of those people it infects. Even if the disease is diagnosed early and treated with appropriate drugs, the case fatality rate remains 5-10%. As many as one out of five survivors will suffer from neurological after-effects such as deafness or mental retardation (83). The highest burden of meningococcal disease occurs in sub-Saharan Africa, which is known as the “Meningitis Belt”, an area that stretches from Senegal in the west to Ethiopia in the east. This hyper-endemic area is characterized by social habits and a particular climate (82).

The distribution of epidemics is dependent on a wide variety of factors including immunological susceptibility, bacterial strain, demographic and socioeconomic factors, environmental factors, and the presence of other infections(83). The IPCC 4th assessment report indicated that climate change and variability have an impact on the epidemiology of meningitis, especially in countries within the ‘Meningitis Belt’ in semi-arid sub-Saharan Africa where they experience the highest endemicity and epidemic frequency of meningococcal meningitis (2). Climate change affects both weather (heat, humidity, wind) and the environment (extent of vegetation or desertification); it intensifies those factors
that most determine meningitis outbreaks, particularly humidity (drought) and dust levels for areas that will become more arid.

Figure 4. African Meningitis Belt. Source: World Health Organization (84).

Several studies have addressed the seasonality of meningitis. Gessner et al. found that similar to meningococcal meningitis, pneumococcal meningitis was seasonal, occurring primarily in the dry season (85). Obikar also concluded that climate factors are important for both the distribution and the seasonality of meningococcal disease; the distribution of sero-groups causing meningococcal disease (A, B, C, Y, W-135) varies over time and by geographic location and the spatial distribution of the disease indicates a close linkage with weather climatology (82). Large epidemics occur during the dry season, between December and June, in the meningitis belt area (82). This pattern has been attributed to effects of dust winds and upper respiratory tract infections, due to cold nights, on the local immunity of the pharynx, thereby increasing the risk of meningitis. An analysis using climate/environmental models to predict the probability of occurrence of meningitis epidemics in Africa’s meningitis belt revealed that
anomalies in annual meningitis incidence at the district level were related to monthly climate anomalies. Significant relationships were found for both estimates of rainfall and dust in the pre-, post- and epidemic seasons. While present in all land-cover classes, these relationships were strongest in savannah areas (86).

Recent analysis of reported epidemics indicate that there appears to be a southward shift in the distribution of epidemics over time, with newly affected areas south of the current meningitis belt consistent with changes in the region’s climate/environment in many areas (83). A predictive model based on all known meningitis epidemics occurring before 2000 in African countries revealed that epidemics of meningococcal meningitis occur in areas with particular environmental characteristics. Absolute humidity, dust and rainfall profiles, land-cover type, and population densities were independently associated with the location of epidemics. However, it was found that the absolute humidity profile and land-cover type were the best predictors in the final multivariable model (87).

**Meningitis in Ethiopia**

Ethiopia is within the meningitis belt, and is cyclically affected by epidemics of meningitis. Since the first reported outbreaks of meningitis in 1901, there have been repeated occurrences: 1935, 1940s, 1950s, 1964 and 1977, followed by the largest epidemics in 1981 and 1989, each affecting almost 50,000 people (88)). SNNPR and Oromiya have been most severely affected in the past, with Amhara, Gambella, and Tigray also seeing significant impact (89).

Recent studies indicate that there has been expansion of certain sero-groups of meningitis in Ethiopia beyond the areas traditionally included in the meningitis belt (90), mainly consistent with changes in the region’s climate/environment in Southern Province in Ethiopia (83). A 2013 press release by the Federal Ministry of Health stated that a meningitis outbreak occurred in some parts of the Southern Nations, Nationalities, and Peoples State. It is also stated that outbreaks of meningococcal meningitis often occur during the dry season, particularly from December to June when dusty winds and respiratory infections are present (91).

Local studies which relate meningitis with environmental and climate variation are lacking in Ethiopia. However, a recent retrospective study by Ahmed (92), based on cases of bacterial meningitis in Gondar University Hospital, found a marked effect of seasonal variation, with more cases occurring in the summer months. Almost 35% of the cases of bacterial meningitis at Gondar were recorded in the months of May and June. Culture-specific results show that this variation was most pronounced in meningococcal disease in which almost two-thirds of the cases (67%) occurred in the dry season during the second quarter of the year, i.e., April to June. Among the various agents of bacterial meningitidis, Streptococcus pneumoniae was the most common organism identified in the CSF cultures of 35 patients (35.3%). Next were Neissseria meningitides from 27 cases (27.3%) and Haemophilus influenza from 9 cases (9.1%)(92).
Air Quality

The Ethiopian Climate Resilient Green Economy document (7) identifies air quality as an area that will likely be adversely affected by climate change. The main factors that could impact air quality are air pollution and changes to seasonal/regional allergens. These threats will likely be exacerbated by increases in temperature and rainfall variability.

Air Pollution in general

Air pollutants such as particulate matter (PM) and ozone have been found to have negative health effects including decreased lung function, asthma, and chronic respiratory diseases, as well as increased risk for heart attack. The effects of air pollution tend to be intensified with high levels of heat (93). Studies have suggested that excess heat increases morbidity and mortality from cardio-respiratory disease in those exposed to ozone and PM, with greater risk associated with the elderly or those with pre-existing vulnerabilities (84).

Many air pollution models have indicated that temperature is the strongest meteorological variable affecting concentrations of ozone in polluted areas, with an increase in temperature correlated to high levels of ozone (94). Additionally, periods of drought have been associated with increased airborne dust, thus increasing levels of PM.

Air Pollution in Ethiopia

Air pollution in Ethiopia has not been extensively researched. Etyemezian et al. (95) conducted a pilot study in 2004 to assess the ambient air quality in Addis Ababa. The authors determined that ambient outdoor PM$_{10}$ and PM$_{2.5}$ levels approached, if not exceeded, standards set by the Ethiopian EPA (96). These findings indicate that temperature increases associated with climate change have the potential to greatly impact air quality, especially during a period of drought.

As of 2006, lower respiratory infections were the leading cause of death in Ethiopia (42) as a result, outdoor and indoor air pollution is a major concern in the country. A study looking at indoor air pollution in rural Butajira found seasonal and ecological variations in indoor air pollution concentrations. Considering the spatial-temporal variation of the monthly mean nitrogen dioxide (NO$_2$) concentrations, there are clear variations, although the highest concentrations of NO$_2$ appear to be in the main rainy season, from June-September (97). These findings suggest that seasonal and ecological variability has the potential to affect indoor air pollution levels.

Fires

Wildfires caused by drought and extreme temperatures have the potential to serve as a major source of PM. For example, in 2003 a heat wave was associated with a record number of wildfires and poor air quality attributed to PM and ozone in Europe (94).
In some parts of Ethiopia, pastoralists are suspected of starting fires to maintain their land. Although technically illegal, such fires are said to increase growth of vegetation for grazing, decrease the prevalence of ticks or other pests, and decrease predator attacks (98). With increased temperatures or seasonal drought, such fires have the potential to grow out of control. In 2000, The Foreign Agricultural Service reported outbreaks of forest fires throughout southern Ethiopia. Due to the extended drought, these fires, which were attributed to pastoralists, burned about 250,000 acres of forest and 10-15% of Nechi Sar National Park.

Around the world, respiratory disease has been attributed to outbreaks of wildfires (93). Fires burning out of control not only pose a risk to air quality, but also to the physical safety of those nearby, as well as the threat of property loss.

**Allergens**

Allergens are likely to be affected by seasonal changes in climate. Although no studies have explored the role that allergens play in respiratory health in Ethiopia, a number of studies have been conducted exploring this concept worldwide.

Patterns of airborne pollens, fungal spores, and mold will likely be altered with changes in seasonal climate, rainfall and humidity levels. Increases in temperature and high concentrations of carbon dioxide (CO₂) have been associated with increased pollen production of plants and longer pollen seasons (99). Increases in humidity have been associated with the production of fungal spores linked to hospital admissions for (100)asthma.

Pollutants such as PM and ozone have been shown to exacerbate allergy and asthma symptoms when allergens are present (101). The combination of air pollutants and changes in allergens due to climate change are anticipated to worsen allergic disease and asthma, particularly in children (101).

**Nutrition and related impact**

**Overview**

Climate change affects nutrition through various causal pathways that impact food security, sanitation, water and food safety, health, maternal and child health care practices, and many socioeconomic factors, and will increase the risk of hunger and under-nutrition over the next few decades; it challenges the realization of attaining human rights for health and adequate food. Climate change also has an impact on water availability and quality, sanitation systems, and food safety, and on water-borne, food-borne, vector-borne and other infectious diseases which eventually both increase nutritional needs and reduce the absorption of nutrients and their utilization by the body (102).

A study in the West-Arsi zone in Ethiopia which examined local climatic trends and their impacts on livelihoods shows that the trend of gradual and extreme weather change is particularly negative for the livelihood of people in the midlands and lowlands. On the other hand, drought, rain delay, erratic
precipitation, and heavy and unseasonal rain are challenges to the livelihood of the whole region. These conditions force the community to save, diversify, change the growing season, increase mobility, and sell wood and livestock, as well as adopt social interconnectedness as coping strategies (103).

With a likely change in the patterns of climate-related extreme events, such as heat waves, droughts, storms, heavy precipitation and floods and increased risks of disasters, vulnerable communities and households will suffer serious setbacks with regard to food and nutrition security (102). The fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) concluded that under-nutrition linked to extreme climatic events may be one of the most important consequences of climate change due to the very large numbers of people that may be affected (4).

**Nutrition and related impact in Ethiopia**

A study which assessed the prevalence of rural and urban food energy deficiency in selected African countries showed that Ethiopia ranks as the fourth most food insecure country in the sample using FAO data, but the most food insecure country using household data (104). In addition, low agricultural yields and average farm sizes, land degradation and deforestation, and chronic problems with food security are already evident in Ethiopia (105). Climate change is projected to reduce yields of the wheat staple crop by 33%, further contributing to poverty in Ethiopia(15).

The impacts of climate change on nutrition and health will further aggravate the effects of the HIV pandemic, reducing the workforce dedicated to agriculture and the food supply (106). This is a great concern considering that most of the populations affected by HIV depend on agriculture for their livelihoods. Climate change will also put a further strain on the already heavy workload of women, with negative impacts on their ability to provide proper care to infants and young children, heightening the risk of under-nutrition (106).

In Ethiopia and Kenya, two of the world’s most drought-prone countries, children aged five or less are, respectively, 36 and 50 percent more likely to be malnourished if they were born during a drought. For Ethiopia, that translated into some 2 million additional malnourished children in 2005 (61).

Recent vulnerability mapping reports also confirmed Ethiopia’s high vulnerability to climate change with the least capacity to respond(26). The same study argues that climate change will be a major challenge to the country’s efforts to achieve food security and environmental sustainability.

In areas of Ethiopia where drought is more frequent, such as Shinile and Borena, pasture and water scarcity are leading to low conception rates and poor health of lactating animals. This has an adverse implication on the availability of milk and milk products for home consumption (23). It has been concluded that higher temperatures and increased rainfall unpredictability, combined with increasing land degradation and bush encroachment, will result in increased food insecurity and nutritional deficits, unless pastoralists switch to better-adapted livestock species. The impact of food insecurity and malnutrition is more severe on poor households, who usually do not have the financial capacity to modify their herd composition (23).

Unless health services, which are currently very poor in Shinelie and Borena, are improved in the coming years, increased food insecurity and malnutrition are likely to decrease labor productivity and human resistance to diseases, and increase human
mortality (23). In Afar, among the indirect impacts of climate change-related exposure on human health are food insecurity, malnutrition, and poor child growth and development (21).

Mental health

Displacement or property damage due to flooding, economic losses due to drought, and loss of life due to illness will likely take a toll on the mental health and well-being of a population. Worldwide there have been numerous studies examining the impact that extreme weather events, such as hurricanes or typhoons, have on the mental health and well-being of those affected. The losses from such events may lead to post-traumatic stress disorder, anxiety, and depression. Increased risk of suicide and issues with substance abuse are also common. These mental health consequences of extreme weather events have potential consequences for physical health, as they have been linked to medical problems such as heart disease, hypertension, and diabetes (107).

Agriculture

Ethiopia’s economy and the social wellbeing of its population are already subject to climate variability and weather extremes. Agriculture, primarily rain-fed and highly sensitive to fluctuations in rainfall, forms the basis of the economy, providing approximately 46% of GDP and jobs for 80% of the working population. Chronic food insecurity affects 10% of the population and even in average rainfall years, these households cannot meet their food needs: they rely partly on food assistance. Droughts can result in sharp reductions in agricultural output and related productive activity and employment, with multiplier effects on the economy. Floods regularly cause crop and infrastructure damage and widespread suffering and hardship; for example, in 2010 several tens of thousands of people were displaced and over ten thousand hectares of cropland were inundated in the Afar and Amhara regions.

The close links between climate and Ethiopia’s economy are reflected in the strong relationship between GDP growth rate and rainfall variability. Because Ethiopia’s economy and the well-being of the Ethiopian people are closely linked to agriculture and the use of natural resources – water, land, forests, biodiversity, and fisheries – adaptation and action towards climate resilience will come in part through focusing on improving performance and management in these areas with future climate change in mind.

Generally, the livelihood of pastoralists and agro-pastoralists, who are highly dependent on natural resources for livestock-keeping, cropping, fishing, beekeeping and hunting, is very sensitive to climate change. However, because of differences in wealth, power, social values, and natural resources within the communities, their vulnerability and ability to adapt to climate change also vary in time and space. The range of vulnerability within the pastoralist community can be broadly classified as follows (39):

- The most vulnerable to climate change are usually elderly men and women and children.
- The poor with fewer livestock and less voice in decision-making in the community are more vulnerable; women heads of household are usually classified as poor.
• Minorities within the clans and sub-clans, engaged in fishing, beekeeping and hunting, are more vulnerable than the majority and more powerful, who are engaged in keeping livestock.

• Those who rear mainly cattle and sheep are more vulnerable than those rearing camels and goats, which are more resistant to drought.

• People living in critical areas such as flooded regions and who are bounded by different conflicting ethnic groups are more vulnerable than people in other locations.

• Agro-pastoralists with limited mobility are more vulnerable to climate change than are nomadic pastoralists.

In Ethiopia, agriculture remains by far the most important sector and it directly supports about 85% of the population with regard to employment and livelihood. This sector contributes about half of the country’s gross domestic product (GDP). Agriculture is particularly sensitive to climate change. Greater total or more intense rainfall across the country may increase soil erosion and the occurrence of crop damage. Ethiopia is particularly vulnerable to accelerated soil erosion because of existing pressures and degradation on its land area, 79% of which has a slope of greater than 16%, with 25% having a slope of greater than 30%. Changes are also expected to occur to production system viability; cropland area and cropping patterns; pest and disease frequency and distribution brought about by changes in seasonality; timing and distribution of rainfall; higher evapotranspiration; and drought and flood damage.

As noted earlier there are no country-wide, methodologically consistent, climate impact studies for Ethiopia. Agricultural studies show a diverse set of impacts, including decreases in suitable rain-fed land areas and potential cereal production, but also some positive impacts on growing-season length by the 2080s (108). Livestock yields will be impacted directly through temperature effects on annual growth, milk and wool production and reproduction; and indirectly by changes in the quantity and quality of pasture, forage, grass, and disease and increases in parasites. The negative impacts of climate change may be particularly experienced by pastoralist communities. The interactions between these problems and potential benefits of greater CO$_2$ ‘fertilization’ are largely unknown.

Crops

Agriculture is dominated by rain-fed small-scale farming, primarily based on traditional technologies. Modern inputs, in particular fertilizers, are comparably low, at an average of 81 kg/ha (109). Small-scale subsistence farming accounts for 95 percent (about 8 million peasant households) of the total area under crops, and more than 90 percent of total agricultural output. Although the arable area has expanded slightly in recent years, population growth has outpaced this expansion. Average landholding per household has dropped to below 1 ha. Average yields remain low, at only 2.1 t/ha for maize, 1.7 t/ha for wheat, 1.4 t/ha for teff and 1.25 t/ha for barley (110). Although the importance of agriculture, as measured in terms of its contribution to GDP, has decreased in recent decades, the overwhelming majority of the population is still mainly rural and depends heavily on agricultural income.

Conway and Schipper (111) used the ‘Livelihoods, Early Assessment and Protection’ (LEAP) software platform to simulate changes in yield of the five main staple crops in Ethiopia under the full range of climate model projections of dry (-19%), average (+1%) and wet (+19%) rainfall for the 2020s. The crops...
simulated were maize, teff, barley, and sorghum with a short and long maturity cycle. The effects of climate change were calculated as differences between the period with observed data (1995-2008) and the same period with rainfall adjusted according to the climate model projections. Higher rainfall produced modest effects on yield, not always consistent, with increases in most years and very small decreases in some years. Lower rainfall had greater impacts on yield for all five crop types and produced more consistent reductions in yield in nearly all years.

Changes in crop yield were used to calculate changes in LEAP, the estimated number of beneficiaries needing food assistance, and the consequent livelihood protection costs in areas where the Productive Safety Net Programme (PSNP) operates (using algorithms from 2008). Figure 5 shows the effects of changes in crop yield under future rainfall conditions, on the estimated total number of beneficiaries, expressed as a percent change from the baseline period average. The scale shows percent changes because the relationships used to calculate the index are provisional and still under development. The full line shows results, with observed rainfall having notably high values between 1999 and 2002, 2004 and reflects the major drought in 2002. The effect of the dry rainfall scenario (short dash) leads to an average increase of 32%, in the total number of people needing assistance across all years. The higher rainfall leads to an overall average reduction of 11% in beneficiary numbers. The multi-model average change in rainfall (not shown) gives results very close to those estimated for the present day.

Figure 5: Per cent change from long-term average (1995-2008) in total beneficiaries in the PSNP under different climate change projections for the 2020s. Grey solid line 100% rainfall, long dash wet extreme, short dash dry extreme.

Livestock

Ethiopia has the largest livestock population in Africa and the tenth largest in the world. Livestock is an integral part of the farming systems in the country, and the source of social and economic values such
as food, power, fuel, cash income, security, and investment. The livestock sector is estimated to contribute approximately 12 to 15 percent to total GDP and about 25 to 30 percent to agricultural GDP (112).

Jones and Thornton (113) assessed livelihood transitions to 2050 in Africa due to climate change and found that changes in the frequency and severity of extreme climate events could have significant consequences for livelihoods, natural resources, food production and food security. Increasing frequency of heat stress, drought, and flooding events are projected to have adverse effects on crop and livestock productivity, in addition to changes in mean climate. Thornton et al. (2009) reviewed the impacts of climate change on livestock and livestock systems in developing countries and considered knowledge gaps. They highlighted key issues around the quantity and quality of feeds, changes in atmospheric CO₂ concentrations, and temperature impact on growth rates. They noted that climate change could have many indirect and unpredictable impacts on infectious animal diseases throughout Africa; for instance, combinations of drought followed by high rainfall have led to wide-spread outbreaks of diseases such as Rift Valley Fever and bluetongue in East Africa. Finally, droughts may force people and their livestock to move, potentially exposing them to environments with health risks to which they have not previously been exposed (114).

**Transport**

Although improvements have been made to Ethiopia’s transport infrastructure, in 2008 the road network was 56,113km long, of which 85% was unpaved. Improvement and maintenance of transport links between urban centers, to and from ports of export and import, and in particular to rural areas are pre-requisites for economic development. Transport links -- both paved and unpaved roads -- are highly vulnerable to the increases in rainfall and temperature which are projected for Ethiopia, with heavy rainfall washing out roads and high temperatures damaging road surfaces.

A World Bank study (115) projects that climate change will increase the maintenance costs of the country’s road network by between $10 million to $21 million annually, depending on the climate model used. These costs will be reduced and transport links maintained if road drainage and bridge designs are adapted to the expected climatic conditions. Maintenance costs of unpaved roads are also high, and extending the network of paved roads is likely to be economically beneficial.

**Industry**

Ethiopia’s economic development will require an expansion of industrial activities. Some of the industrial sectors, such as textile and leather, will allow increases in exports; others, such as cement and steel, will expand largely for domestic infrastructure development. While the growth of Ethiopia’s industrial sectors has the highest priority, challenges relate to greenhouse gas (GHG) emissions caused by these activities. Ensuring the transfer of modern and resource efficient technologies is therefore an important component of Ethiopia’s growth plans.
Water

River flows tend to increase

Recent studies of river basins in East Africa, including Ethiopia, using a range of climate model results, show a tendency for higher river flows due to higher rainfall (increases in rainfall large enough to offset greater losses to evaporation). A minority of models (less than half those used for IPCC 2007) still show decreases in rainfall and river flows.

Flooding may increase

Although no studies have directly considered changes in flood characteristics, it is very likely that flood frequency and magnitude will increase under higher rainfall conditions.

River flows are highly sensitive to rainfall changes

Modeling studies of the Awash and Abay (Blue Nile) show that both rivers have high sensitivity to climate change. A set of modeling studies for the region show that most hydrological systems are more sensitive to changes in rainfall than to changes in temperature/evaporation.

Lake Ziway Watershed Water availability

Abraham (116) applied the changes in rainfall and temperature to the Lake Ziway Watershed using one climate model to a hydrological model to simulate future flows and concluded the following:

- Except during the 2001-2025 period, the total average annual inflow volume might decline significantly by up to 19.47% and 27.43% for different scenarios.
- This inflow volume reduction is likely to drop the lake level about 0.66m.
- The surface area might shrink by 25.3 km$^2$.

Energy

The vast majority of Ethiopia’s national energy needs are met by fuel wood, crop and animal waste, and human and animal power. Only 5% comes from electricity and 95% of this is generated by hydro-power. Much of Ethiopia’s hydro-power potential has yet to be developed. This energy mix greatly increases the country’s vulnerability to climate change. For example, Ethiopia’s reliance on fuel wood and charcoal brings widespread land degradation, exposing bare soil to erosive rainfall and gulley erosion. As the impact of climate change increases, there is likely to be a higher reliance on forest products for livelihoods.

Energy generated by hydropower is also vulnerable to fluctuations in rainfall, temperature, and evaporation. For example, reduced power production during drought years already takes a significant toll on the economy. In 2002/3, the power supply was lost one day a week over four months because of
drought, causing a sustained reduction in economic productivity. Loss of electricity also has an impact on basic services, especially in schools and hospitals.

Ethiopia plans to increase its hydroelectric power production significantly to satisfy its own growing needs and to supply its neighbors. While these plans offer huge potential to power low carbon growth in Ethiopia and beyond, they need to be carefully considered for implications of future climate change so that benefits can be sustained and conflicts with other water users can be avoided.

**Impacts of Climate Change on the Economy**

Ethiopia has experienced strong economic growth in recent years. With real GDP growth at or near double-digit levels since 2003/04, the country has consistently outperformed most other countries in Africa. Official figures show real GDP growth averaged 11.2 percent per annum during the 2003/04 to 2008/09 period, putting Ethiopia among the fastest growing economies in sub-Saharan Africa. Although IMF estimated growth rates around 7.5 percent in 2010–11 (117) lower than government estimates of 11.4 percent, this growth performance is still in excess of the population growth rate and the 7 percent rate required for attaining the MDG goal of halving poverty by 2015 (118).

To assess the impacts of climate change, it is necessary to estimate the impacts and costs of climate/weather events on socio-economic activities, based on observations. In many countries information (qualitative and quantitative) on costs is not readily available, because it is rarely recorded in a consistent manner over time, is difficult to estimate, and --where it does exist-- is often in a form that requires additional work to be useful for the type of work required here. The main climate hazards in Ethiopia are associated with rainfall extremes—droughts and floods—and variations in the timing of rainfall (onset and breaks in the rains). These are the events that we analyze in detail and it is through changes in their frequency and magnitude that climate change is likely to be manifest and most significant in socio-economic terms. Gradual warming will bring the slow onset of change throughout the country, and although of heat waves will occur with increased frequency, there is very little information on their effects in Ethiopia at present.

**Quantifying economic impacts**

Until recently very little work had been done to quantify the economic effects of climate variability or extremes in Ethiopia, despite the high profile and significant impacts that droughts have had. In fact, this is the case globally — although this is now being addressed, particularly since the Stern review, but also since earlier work by the World Bank, (119). The earliest empirical economic analysis for Ethiopia was commissioned as part of the World Bank water strategy paper (120).

Conway and Schipper (111) highlight sensitivities within the economy, such as effects on GDP, consequences for the external sector, and prices. The effects are clear in the major drought years of 1984 and 2001; however, in other years, the relationship between a national estimate of rainfall and economic performance/behavior is not systematic and relationships cannot be readily identified. This
gap has implications for estimating economic effects of future climate change because such projections need to be based on robust and stable relationships that can be used for future climate conditions.

**Modeling the links**

Robinson et al. (121) simulated the economic impacts of climate change for 2050 using a multi-sectoral regionalized dynamic computable general equilibrium model. The researchers concluded that climate change would reduce Ethiopia’s GDP in the 2040s up to 10 percent, with greater negative effects on the poorer households. The results suggested that with support from developed countries, suitably scaled adaptation measures could restore aggregate welfare to baseline levels.

Deressa and Hassen (122) analyzed the economic impact of climate change on crop production in Ethiopia and concluded that climate, household, and soil variables have a significant impact on the farmers’ net revenue per hectare. Their results also suggested that both rising temperature and declining precipitation are damaging to Ethiopian agriculture. The net crop revenue impact of predicted climate scenarios from three models (CGM2, HadCM3, and PCM) for the years 2050 and 2100 indicated a reduction in crop net revenue per hectare by the years 2050 and 2100. On this basis, they concluded that increasing temperature marginally during winter and summer reduces the net revenue per hectare by US$997.85 and US$1277.28, respectively. Their results also indicated that reduction in the net revenue per hectare will be greater in the year 2100 than 2050 under all scenarios. They suggested that different agro-ecological zones are not uniformly affected by future changes in climate.

The World Bank (5) analyzed the economic impacts from climate change and potential adaptation policies in Ethiopia using a dynamic Computable General Equilibrium (CGE) model calibrated to the 2001/02 social accounting matrix. The results indicated that as the climate shocks become more negative, the impact would be much more serious and result in an average decline in average annual real GDP growth rate over a 25-year simulation horizon.

Gebreegziabher et al (123) used a dynamic CGE model to grasp the economy-wide effect of climate change-induced shocks in agriculture on Ethiopia’s economy. The study found that over a fifty-year period the projected reduction in agricultural productivity may lead to reductions in average income of about 30%, compared to what would have prevailed in the absence of climate change. The study also found that in those parts of the moisture-sufficient highlands where cereal production currently dominates, overall productivity is projected to increase until approximately 2030 because of climate change, but to decline sharply thereafter. In the drought prone highlands, the situation is somewhat different. Land productivity in crop production is expected to decline because of climate change more or less continuously throughout the period.

Zenaye (124) studied the impact of climate change on household poverty in Ethiopia using a dynamic micro-simulation approach and concluded that climate change will negatively affect production and consumption in the country by 2050. However, the impacts are not uniform across the different agro-ecological zones. An exception is in the areas of the pastoralist households where there in an increment in income and consumption of households up to the 2040s. The households in the drought-prone areas
will be the hardest hit and are projected to sustain declines of household consumption expenditure by 30.3 percent. In urban and rural non-farming areas, climate change in 2050 is forecasted to bring a fall in household consumption between 14 and 15 percent. At the national level, total consumption of poor households will decline by 21.4 percent while the consumption of non-poor households will decline by 17.0 percent. The results further indicate that climate change will negatively affect the country’s target of poverty reduction. According to the results of the analysis, poverty and inequality will be exacerbated by the effect of climate change in 2050. The impact of climate change raises the national poverty prevalence from 29.6 percent in 2010/11 to 45.15 percent in 2050. Poverty will be worsened in both rural and urban areas, causing the total number of poor people in the country to rise significantly. Climate change will also increase the inequality among households from its level of 29.8 percent in the base year to 33.2 percent in 2050. Hence, different adaptation and mitigation measures are vital if the country is to achieve its growth and poverty reduction targets.

Solomon (125) examined the impact of climate change on agricultural production until 2050 using the DCGE model and concluded that the overall economy could worsen through changes in agricultural productivity. The reduction in total agricultural crop production will also affect the industry, leading to higher losses in vegetable products (29.6 percent), grain mill products (27.6 percent), and prepared food (24.9 percent) by 2050, as compared to the baseline. With regard to the service sector, trade is projected to decline by 33.9 percent, while hotel service will decrease 24.3 percent by 2050. Climate-change-induced higher national food prices will lower overall Ethiopian GDP growth, factor income, and decrease real household incomes and consumption. The poor rural households will be more affected than urban and rural non-farming households, and the value of exports and imports will fall by 35.7 and 32 percent in 2050, respectively.

You and Ringler (126) simulated the period 2003–50 in Ethiopia using a multimarket model to analyze the effects of changes in water constraints, food damage, and fertilization on economic indicators such as agricultural GDP growth, overall GDP growth, and poverty. Based on this simulation, they concluded that the incremental variability of precipitation, which translates as fluctuating rainfall, reduces the availability of a stable water supply and increases the risk to the food supply. They concluded that climate change is expected to intensify the already high hydrological variability and frequency of extreme events with a significant negative effect on the development of the agricultural sector and on the Ethiopian economy as a whole. Droughts impair agricultural productivity and may lock subsistence farmers into poverty traps, whereas recurrent flooding can have long-term negative effects on agricultural GDP by directly damaging crops and by destroying roads, thereby exacerbating the inadequacy of transport infrastructure and consequently limiting access to markets.

Policy, Adaptation and Response to Climate Change

Policy

The Ethiopian Government has already put in place a number of policies, strategies, and programs aimed at enhancing the adaptive capacity and reducing the vulnerability of the country to climate variability and change. Such programs include the Plan for Accelerated and Sustainable Development to
End Poverty (PASDEP), the Environmental Policy, and the Agriculture and Rural Development Policies and Strategies. The Environment Policies of Ethiopia (EPE) and Conservation Strategy of Ethiopia (CSE) are the two umbrella instruments concerning environmental management in Ethiopia. These instruments were approved in 1997 and responded to the then-apparent environment and development challenges of the country. Most policy recommendations contained in the EPE and CSE are very much relevant to climate change mitigation and adaptation (127).

In 2005, Ethiopia formulated its five-year MDG-based Medium-Term Development Plan entitled “A Plan for Accelerated and Sustained Development to End Poverty (PASDEP 2005-2010)” (128). PASDEP I has clearly identified that atmospheric pollution and climate change are the causes of considerable environmental and socio-economic problems (PASDEP, 2005). The impacts of climate change and atmospheric pollution include weather variability, loss of pastureland, droughts, flood and thus food insecurity, and other environmental related health problems. Proposed intervention measures include developing a federal strategy, standards, and laws to improve urban air quality; developing a national strategy to enhance coping mechanisms regarding the adverse impacts of climate change; and launching environmentally sound investment and other programs that foster cleaner development mechanisms, including emissions trading. Ethiopia’s Growth and Transformation Plan (GTP) was recently prepared (2010/11-2014/155) with the objective of building a carbon-neutral and climate-resilient economy (129). Enforcement of the existing environmental laws is a priority in connection with environmental conservation and climate change. The formulation and implementation of climate change adaptation and mitigation program are highlighted as priority activities.

Building on the positive trajectory of growth during the last ten years in Ethiopia, the Growth and Transformation Plan (GTP) -- the main government policy instrument that guides the major economic and social development efforts of the country -- sets a goal for achieving double digit growth that will elevate the country to that of middle-income country level by 2025, while at the same time becoming climate-neutral. The Government of the Federal Democratic Republic of Ethiopia has initiated the Climate-Resilient Green Economy (CRGE) initiative to protect the country from the adverse effects of climate change and to build a green economy that will help realize its ambition of reaching middle-income status before 2025. Following the Bali Road Map and the Copenhagen Accord, Ethiopia is preparing itself to tackle climate change involving two concurrent approaches: Mitigation (actions that tackle the causes of climate change, such as reducing greenhouse gas emissions), and Adaptation (actions that minimize the consequences of actual and expected changes in the climate).

**National Adaptation Program of Action (NAPA)**

The government of Ethiopia recognizes the impact of climate change on health, and has developed a Climate Change Adaptation Program Plan for Health for the years 2011-2015, with the anticipation that this strategic plan will help overcome the health risks of climatic change that the people of Ethiopia have been facing for many years (130). The document outlines how climate change affects human health directly through increasing morbidity and mortality as a result of temperature extremes, increasing vectors of infectious diseases, proliferation of non-vector borne infectious diseases, declining air quality, more frequent floods and storms, and indirectly through impacts on food supply and water resources.
Climate-sensitive diseases such as malaria, trypanosomiasis, onchocerciasis, schistosomiasis, and Leshmaniasis are already common in Ethiopia, and climate change may worsen their impact (130).

In response to the UNFCCC calls for the specific needs and special situations of less developed countries (LDC) to be addressed in the form of Climate Change National Adaptation Programs of Action (NAPA), Ethiopia has prepared “Climate Change National Adaptation Program of Action (NAPA) of Ethiopia in 2007” (15). Central to the NAPA process is the integration of climate change adaptation activities with national development policies to ensure their effective implementation. The NAPA process in Ethiopia identified arid, semi-arid, and dry sub-humid areas of the country as the most vulnerable to drought; agriculture was identified as the most vulnerable sector; and, with regard to livelihoods, small-scale rain-fed subsistence farmers and pastoralists are identified as those most at risk. The NAPA process has identified and prioritized eleven project areas that address the immediate climate change adaptation needs in the country, focusing on human and institutional capacity building, improving natural resource management, enhancing irrigation agriculture and water harvesting, and strengthening early warning systems and raising of awareness. Implementation of NAPA activities, however, is not progressing as expected due to financial constraints.

The Climate-Resilient Green Economy (CRGE)

The country’s objective is to identify green economy opportunities that could help Ethiopia reach its ambitious growth targets while keeping greenhouse gas emissions low. The government intends to attract development partners to help implement this new and sustainable growth model and to become a “green economy front-runner”.

The CRGE initiative follows a sectoral approach and has so far identified and prioritized more than 60 initiatives, which could help the country achieve its development goals while limiting 2030 GHG emissions to around today’s 150 Mt CO2e – about 250 Mt CO2e less than estimated under a conventional development path. Implementing the initiatives would also offer important co-benefits such as improved public health through better air and water quality, and would promote rural economic development by increasing soil fertility and food security. The green economy plan is based on four pillars.

The four pillars of the green economy plan are:

1. Improving crop and livestock production practices for higher food security and farmer income while reducing emissions;
2. Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks;
3. Expanding electricity generation from renewable sources of energy for domestic and regional markets;
4. Leapfrogging to modern and energy-efficient technologies in transport, industrial sectors, and buildings.
Nationally Appropriate Mitigation Action (NAMA)

In response to the call of the Copenhagen Accord for the Non-Annex I Parties to prepare and implement Nationally Appropriate Mitigation Actions (NAMAs), Ethiopia has prepared and submitted its NAMA to the UNFCCC secretariat (EPA, 2010a). Key mitigation technologies and practices include the following.

Key mitigation Technologies and Practices in the Ethiopia’s NAMA by sectors:

- **Renewable energy**, including 10 hydro power plants with a total of 5,632 MW that will be completed between 2010 and 2015, 11 under study with a total capacity of 8,915 MW; 7 wind power projects with a total of 764 MW to be completed by 2013; and 6 geothermal projects with a total of 450 MW to be completed by 2018.

- **Bio-fuel Development** to produce 63.36 million liters of ethanol and 621.6 million liters of biodiesel for the market starting from 2010 up to 2015.

- **Electricity Generation from Renewable Energy for Off-grid use and direct use of renewable Energy** including 150,000 solar home systems, 65,000 Small Hydro Projects, 600 wind or solar pumps, 3,000 institutional PV, 3,000,000 solar Lanterns, 3,500 solar water heaters, 10,000 solar cookers, 9,110,000 improved stoves, l25,000 household biogas digesters and 1,000 institutional biogas digesters starting from 2010 up to 2015.

- **Transport**: Construction of 9 national railway routes covering 4,885 KMs to be completed by 2020.

- **Forestry**: reforestation of 21,440 km² degraded lands, lands affected by gullies and slopes, managing 28,736.7 km² natural forests, 4,390.96 km² deciduous forest, 60,360 km² of national parks, and 19,817 km² non-timber forests; establishing 52,695 km² production forests; and managing 51,496 km² wetlands.

- **Agriculture: Composting** 80,000 km² of agricultural land and 261,840 km² of practicing agro-forestry.

- **Waste management**: Landfill methane recovery from 9 landfills from a total of 43 million m³ of deposited waste.

Ethiopia’s Program of Adaptation to Climate Change (EPACC)

Ethiopia’s Program of Adaptation to Climate Change (EPACC) is one of action to build a climate-resilient economy through adaptation at sectoral, regional, and local community levels. The EPACC updates and replaces Ethiopia’s National Adaptation Program of Action (NAPA) which was formulated in 2007 and submitted to the UNFCCC Secretariat. The May 2010 report of the UNFCCC’s Least Developed Countries Expert Group encouraged the updating of NAPAs, suggesting that a more programmatic approach could be more effective than the NAPAs’ the project approach. In line with this suggestion, Ethiopia has reformulated its adaptation program. Ethiopia’s NAPA contained detailed descriptions of some larger adaptation projects, but the formulation of those projects was not as ambitiously participatory as that of the present EPACC.

GEOHealth Ethiopia
The sectoral ministries and all of the Regional Governments are expected to jointly mobilize all the stakeholders down to the local community at the village level in formulating and implementing their responsibilities. About 20 problems and the actors responsible for their solutions have been identified in the areas of health, agriculture, forestry, land management, water, energy, waste, transport, industry, infrastructure, municipalities, and disaster management at various levels (131).

Priority actions to be taken for implementing adaptation measures to climate change

- Identifying the risks posed by climate change and mapping the areas likely to suffer;
- Establishing a simple and practical information network;
- Creating/strengthening a vibrant early warning system;
- Mainstreaming into development and service activities;
- Integrating adaptation to climate change into educational curricula at all levels;
- Enhancing integrated research and development activities on climate change; and
- Accessing financial resources and technologies for the implementation of climate change adaptation.

Institutional Capacity Building

Various GOs, NGOs, and international institutions are engaged in climate change research and advocacy. The major government institutions include the Environmental Protection Authority (EPA), the National Meteorological Services Agency (NMA), Addis Ababa University (AAU), the Ethiopian Institute of Agricultural Research (EIAR), and the Ethiopian Development Research Institute (EDRI). Among the NGOs, the Forum for Forum (FfF), Climate Change Forum (CCF), African Climate Change Resilience Alliance (ACCRA), and Pastoralist forum are worth mentioning, as are UNDP, WFP, WB and Ethiopian Consumers Protection Association (ECPA) among the International institutions.

The Ethiopian Government has established the Environmental Protection Authority (EPA) as the responsible institution to ensure the implementation of the UNFCCC and its Kyoto Protocol in a coordinated and yet decentralized manner. Recognizing the urgency and inter-sectoral nature of the environment, it has also established the Environment Council (EC) by proclamation to provide overall leadership in environmental policy and regulatory systems and to provide high-level oversight of environmental standards and directives. It is chaired by Ethiopia’s Deputy Prime Minister, and its members are Federal Ministries, all Regional State presidents, representative of trade unions, environmental NGOs, and the Ethiopian Chamber of Commerce. It is the highest-level decision-making body in government for the environment. The Environmental Protection Authority is the secretariat of the EC.

These and other national policies are geared towards accelerating growth and transformation to lift the country out of the cycle of poverty and to meet the national vision of a middle-income Ethiopia. In light of this national interest, climate change provides both a challenge and an opportunity to reconfigure the country’s development strategies so as to realize sustainable development.
Gap analysis

This review shows that much has been accomplished and there is recognition of the significance of climate change for Ethiopia at the highest levels of government. Yet gaps are evident. Climate change-related health outcomes have not been adequately studied in Ethiopia to guide the development and implementation of adaptation and mitigation strategies. Therefore, the main gaps identified through this SANA are presented below.

Organizational gaps

The SANA has identified various national organizations working on climate change-related activities in Ethiopia, including the Environmental Protection Authority (EPA), and the Ministries of Health, Agriculture and Water Resource. The EPA of Ethiopia has been mandated to coordinate the national response to climate change in the country. It has recently launched an ambitious Climate Resilient and Green Economy (CRGE) strategy including the Nationally Appropriate Mitigation Action (NAMAs) plans and the National Adaptation Plan (NAP). There have been various barriers, however, that impede the implementation of different strategies adopted on climate change by the organizations. The main gaps related to organization include:

• Lack of a well-organized structure in the regional branch offices of the EPA, and merging of the EPA and regional land administration offices.

• Lack of inter-sectoral collaboration among the organizations working on climate change-related activities. The poor linkages between the organizations such as the National Meteorology Agency (NMA), the Ministry of Health, and the Ministry of Agriculture with the academic and research institutes have been recognized.

• Although the impact of climate change has been identified by the various organizations, there are no strong specific units in each institution that can lead and organize the climate change-related activities. Though the PHEM at the MOH is responsible for 24 reportable diseases with potential outbreaks related to climate change, the regional health bureaus are not self-sufficient to handle the outbreaks. The regional health bureaus usually expect a national-level response for such problems.

• Poor coordination and communication exist among the various stakeholders on climate change and health.

• The involvement of the private sector in the endeavors of climate change and health is highly limited.

Training gaps

• Staff currently working on climate change and related outcomes in the various organizations are inadequately trained in the specific relevant techniques relating to climate change and health.
• Lack of training on special skill development, e.g., carbon trade negotiation, geospatial analysis, and hazard mapping, is a reality.

• Most authorities and other staff in the various organizations lack proper awareness of and knowledge about climate change and health activities.

Research gaps

• There has been inadequate research on climate change-related health outcomes in Ethiopia. As a result, polices and strategies related to climate change and health are not based in a body of evidence specific to Ethiopia.

• Lack of research capacity among experts and equipment limitation to carry out relevant research linked to development are concerns.

• Lack of baseline information on basic climate change indicators, e.g., carbon release of the industrial sector, is a major gap.

• Lack of laboratories relevant for carrying out climate change and health-related research is a serious challenge.

• There is a shortage of funds for research on climate change and health.

• There is a lack of specific training that is required for enabling the research activities, e.g., climate change modeling and longitudinal data analysis.

Institutional capacity

• There is a serious lack of technologies that fit the local setting, as well as and shortage of capital to adopt the new technology. The MOA has identified climate change as a development threat as its impact is evident with the changing pattern of rainfall in the last 3-4 decades, reoccurrence of droughts, and a resulting reduction in GDP. The CRGE strategy was set in 2011 and a case team composed of seven staff was formed to coordinate activities related to the strategy. However, it has not been carried out due to lack of a collective vision and the high cost required for implementation at different levels.

• A number of governmental and non-governmental organizations are working on climate change adaptation and mitigation activities, but their activities are not properly coordinated.

• There is a lack of trained personnel and experts on climate change and health in the organizations, regional offices, and academic and research institutes. Multidisciplinary approaches among the professionals of health, agriculture, climate, and water resources are weak, resulting in fragmented activities with little output.

• A very long and inefficient procurement system exists at many of the organizations.
Financial capacity

- Due to the long-term aspects of climate change, financial capital has been identified as a constraint; this is particularly a challenge for the EPA to implement and realize plans and strategies.

- Even if the funds were available, the absorption capacity in some organizations could present a problem.

Policy gaps

- Policies and proclamations on climate change and health are lacking, and those that do exist are not up-to-date.

- Strategies set for climate change and health, such as the climate change adaptation program plan for health (2011-2015) by the MOH, have not been properly advocated and communicated to the general public, relevant stakeholders, and organizations.

- Policies and strategies are adopted mainly based on international evidence and not on findings related to local climate change and health.

- Climate change was not recognized as a public health threat in the 1994 health policy of the country.

- The existing policies do not address the gender dimensions of climate change.

Monitoring and evaluation

- No proper monitoring and evaluation of the climate change situation and its impacts is currently being undertaken.

- The data on climate change sensitive diseases and other health outcomes are not aligned with climate change.
Needs assessment

Organizational needs

- Financial and technical support to implement plans and strategies on climate change and health.
- Well-organized structures in the regional branch offices at the various levels.
- Strengthening Strong inter-sectoral collaboration among the organizations working on climate change-related activities.
- Strong communication and exchange of information among different stakeholders on climate change and health.
- Encouragement and advocacy for involvement by the private sector in the endeavors related to climate change and health.

Training needs

- Train experts on climate change and health through short- and long-term courses. There need to be improved incentives and salary for the experts.
- Create awareness among the community about climate change and health issues.
- Develop curricula on climate change and health should be developed and instituted in undergraduate and graduate programs.
- Train personnel trained specifically in climate change-related science.
- Training personnel on special skill development, e.g., carbon trade negotiation, geospatial analysis, and hazard mapping.

Research needs

- Coordinate implementation of research on climate change and health.
- Strengthen individual and organizational research capacity at various levels, including academic and research institutes.
- Strengthen collaboration between the academic and research institutes and the NMA and other organizations.
- Foster international collaboration between the Ethiopian organizations and academic/research institutes to identify and implement research issues linked to development.
- Retain the trained personnel and experts on climate change and health.
- Establish climate change and health research centers in collaboration with national and international organizations.
- Establish baseline data on critical indicators related to climate change and health.
• Establish and strengthen laboratories necessary for carrying out research on climate change and health.
• Mobilize adequate funding to carry out relevant research on climate change and health that impacts on development.
• Strengthen the research capacity on climate change and health, particularly on climate change modeling and other relevant data management systems.

Institutional capacity needs

• Trained personnel specifically on climate change-related science at relevant institutions.
• Proper coordination and collaboration among the organizations at various levels, with personnel properly trained on climate change and health.
• Provide for appropriate locally sensitive technologies for the organizations that can be applicable at institutional and community levels.
• Promote multidisciplinary approaches among professionals of health, agriculture, climate and water resources.
• Improve the capacity and efficiency of the organizations to utilize meager resources effectively.

Financial capacity needs

• Mobilize adequate financial resources to properly implement climate change and health activities.
• Improve the utilization of financial systems and governance at different organizations.
• Strive for the effective and efficient utilization of meager financial resources.

Policy needs

• Update the existing policies and develop new policies and strategies in line with international and national needs, and including the gender dimensions of climate change.
• Strengthen the collaboration among various organizations to implement the existing policies and strategies effectively.
• Work towards the availability of relevant data for decision making on climate change and health.
• Make climate change part and parcel of the health policy of the country.
• Put in place clear and operational climate change adaptation and mitigation policies and strategies.
Monitoring and evaluation needs

• Establish and strengthen proper monitoring and evaluation systems on climate change and health at various levels in the organizations.

• Work towards the availability of super computers for climate and health data management and processing.

• Work towards the alignment of climate data with health data.

• Publish climate change and health information for the wider dissemination to the global scientific community.

• Establish websites for a wider dissemination of climate change and health information.

• Establish and strengthen scientific and local community forums.

CONCLUSIONS

• Climate change currently represents one of the greatest human development challenges, particularly in low-income countries like Ethiopia.

• The potential impact of climate change on health in Ethiopia has been recognized, but the specific actions and responses have been overlooked. Some of the current impacts of climate change on the country have been manifest in the form of repeated drought, floods, malnutrition, extreme temperature events (extreme heat and cold), and the re-emergence of climate-sensitive diseases. The impact of climate change could also be reflected in the form of increased environmental survival of pathogens and the creation of new ecological niches for vectors, hence changing the epidemiological distribution of diseases.

• Climate impact studies can illustrate the sensitivity of particular systems (e.g., health, agriculture, and water) and the possible direction and magnitude of change in the future. The current stage for research on climate change and health is rudimentary: research findings and other activities tend to appear largely through fragmented, less organized efforts. As a result, no spatially detailed, methodologically consistent climate impact studies are available for the country.

• Poor collaboration among various organizations on planning and executing activities related to climate change and health has been identified, pointing to the need for a better multidisciplinary approach.

• A concern has been identified that the continued climate warming throughout Ethiopia will lead to rainfall irregularity, resulting in poor outputs of rain-fed agriculture. This will be followed by food insecurity and malnutrition.

• This report has clearly documented a lack of trained personnel and expertise on climate change and health in the organizations, regional offices, academic, and research institutions.
Multidisciplinary approaches among professionals in the fields of health, agriculture, climate, and water resources are weak, resulting in fragmented activities with minimal output.

- Lack of well-organized structures in the various organizations and poor inter-sectoral collaboration among them on activities related to climate change and health were identified through this report. Poor coordination and communication among different stakeholders on climate change and health have been recognized.

- Policies and strategies adopted in the country were mainly based on international evidence without taking into consideration local climate change and health-related evidence, and there was a lack of recognition of climate change as a threat to public health. The existing policies and strategies fail to address the gender and community dimensions of climate change.

- The monitoring and evaluation components of climate change and health in various organizations have been identified as weak.

**Priority needs for intervention**

- Increasing community awareness and knowledge on climate change and health through proper media and dissemination forums.

- Increasing the number of trained personnel on climate change and health at the various relevant organizations.

- Strengthening the research capacity on climate change and health through training and technical support for various organizations, including academic and research institutes.

- Establishing climate change and health research centers equipped with adequate laboratory facilities.

- Developing and strengthening national and international research collaborations to carry out relevant research linked to development.

- Updating existing policies and developing new policies and strategies in line with current international and national standards.

- Mainstreaming of climate change and health units at various organizations and academic/research institutes.
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### ANNEXES

#### Annex 1. Key Informants background for GEOHealth Hub SANA

<table>
<thead>
<tr>
<th>Name of organization</th>
<th>Name of informant</th>
<th>Position of key informant</th>
<th>Phone no.</th>
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<tbody>
<tr>
<td>FMOH</td>
<td>Ato Mebratu Maetsentu</td>
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<td>FMOWE</td>
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<td>Ato Abel Yeshaneh</td>
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</tbody>
</table>
### Annex 2. Climate Change-Related Policies and Programs of Ethiopia Policy/Strategy

<table>
<thead>
<tr>
<th>Climate Change Related Policies and Programs of Ethiopia Policy /strategy</th>
<th>Climate change relevant components in the policy/Strategy</th>
</tr>
</thead>
</table>
| 1. Environmental Policy (1997)                                         | • Provide overall guidance in the conservation and sustainable utilization of Ethiopia’s environmental resources  
• Promote environment monitoring programs  
• Foster use of hydro, geothermal, solar, and wind energy to minimize emissions of greenhouse gases  
• Provide coordination and leadership support in conserving and managing environmental resources  
• Consider climate change as a cross-cutting and important environmental, social, and development challenge that needs to be tackled |
| 2. EPACC (Ethiopian Program of Adaptation to Climate Change)            | • Adequately captures the growing threat of climate change in Ethiopia and clearly spells out the need to mainstream climate change in all spheres of development policy planning at all phases and stages of the planning and implementation process  
• Clearly states the urgency of taking practical adaptation and mitigation actions in various social and economic sectors  
• Role of non-state actors in the planning, design and implementation of activities mentioned in the work program is not clearly spelled out |
| 3. Ethiopian NAMA                                                      | • Pays special attention to unleashing the huge potential of the country’s water and geothermal energy resources for the purpose of generating electricity for transport and household consumption, and managing urban wastes  
• Fails to include important mitigation actions in land-use planning, energy efficiency incentives, and traffic management regulatory policy measures |
| 4. CRGE (Climate Resilient Green Economy) strategy                     | • Recommends the use of low carbon solutions to leapfrog other economic sectors while realizing the ambitions set out in the country’s Growth and Transformation Plan  
• Presents an overarching framework to marshal a coherent response to climate change, generate both innovative thinking and a course of actions to meet the challenges associated with the transfer of climate-friendly technologies and finance for the construction of a climate resilient green economy in Ethiopia |
| 5. GTP (Growth and Transformation Plan)                                | • Climate change is recognized as a huge threat and opportunity for Ethiopia  
• Both climate change adaptation and mitigation issues are considered  
• It stipulates the country’s ambition to build a climate resilient green economy |
| 6. RDPS (Agricultural and Rural Development Policy Strategies)          | • Sustainable Land Management Program (SLMP) as a tool to reduce rural vulnerability and building ecosystem resilience  
• Environmental rehabilitation  
• Watershed development for environmental adaptation  
• Harnessing the multiple benefits of water resources  
• Integrated disaster risk monitoring and early warning  
• Use of improved agricultural inputs and modern technologies |
| 7. Energy policy & Biofuels strategy                                   | • Supports energy diversification and the development of modern (renewable) energy sources  
• Advocates for hydro-power generation  
• Recommends biofuel development as important strategy for energy security and climate mitigation  
• However, focuses on hydro- and bio-energy sources |
| 8. Water Policy | • The water sector policy instruments do not factor climate change as a major affecting the amount, distribution, and quality of water resources. But they are important:  
  • Water harvesting and management measures  
  • Flood management  
  • Promotion of equitable water for multiple use |
| 9. Women’s Policy (1993) | • Recognizes the critical role and contribution of Ethiopian women to poverty and sustainable development  
• Fails to address the gender dimensions of climate change |
| 10. Health Policy (1994) | • Focuses on health promotion and disease prevention, curative and rehabilitative services, and public health emergency preparedness  
 • Prioritizes the prevention of environmental pollution with hazardous chemicals  
 • The development of environmental health  
 • Focuses containing and controlling malaria  
 • Does not consider climate change as a major public health threat |
| 11. Climate Change Adaptation Program Plan for Health – (2011-2015) | • Helps to overcome the health risks of climatic change, which the population has been facing for many years while dealing with health problems raised from climatic change |

Source: from the document entitled “A Climate Change Country Assessment Report for Ethiopia Submitted to Forum for Environment (on behalf of ECSNCC) by Epsilon International R&D (132); August 2011, Addis Ababa”.

GEOHealth Ethiopia
## Annex 3: Health effects of Climate Change

<table>
<thead>
<tr>
<th>Prediction</th>
<th>General Effects</th>
<th>Specific to Ethiopia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>Likely to increase</td>
<td>Increased temperatures pose a threat to the health of humans and livestock as well as land degradation. This will likely be exacerbated by periods of drought.</td>
</tr>
<tr>
<td></td>
<td>Urban heat island effect, heat stroke/exhaustion, increased risk of cardiovascular disease, with children, elderly and those with preexisting conditions most at vulnerable.</td>
<td></td>
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<tr>
<td><strong>Floods</strong></td>
<td>Frequency and intensity likely to increase</td>
<td>Periods of flooding are correlated with outbreaks of diarrhea, cholera, dengue, malaria, and other waterborne diseases.</td>
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<tr>
<td></td>
<td>Contaminate freshwater supplies, increased risk of water-borne diseases, causes physical injuries, damage homes and infrastructure</td>
<td></td>
</tr>
<tr>
<td><strong>Droughts</strong></td>
<td>Frequency and intensity likely to increase</td>
<td>By the 2090s, drought is expected to affect a larger area and occur 2x as often and last 6x as long. (4)</td>
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<td></td>
<td>Food insecurity, malnutrition, increase in water scarcity, exacerbated by increased temperatures</td>
<td></td>
</tr>
<tr>
<td><strong>Air Pollution</strong></td>
<td>With a “business as usual” level emissions of ozone and PM, increased temperatures are likely to exacerbate the effects of air pollution.</td>
<td>Studies pertaining specifically to Ethiopia are not yet available.</td>
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<tr>
<td></td>
<td>PM and ozone have been found to have negative health effects, including decreased lung function, asthma, chronic respiratory disease, and increased risk for heart attack</td>
<td></td>
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<tr>
<td><strong>Wild Fires</strong></td>
<td>Likely to increase with periods of drought and extreme heat</td>
<td>Studies pertaining specifically to Ethiopia are not yet available.</td>
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<tr>
<td></td>
<td>Wildfires will likely be a source air pollution (PM), threaten the safety of humans and livestock, and destroy property/infrastructure.</td>
<td></td>
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<tr>
<td><strong>Allergens</strong></td>
<td>Suggested that climate change will impact regional allergens from airborne pollens, fungal spores, mold</td>
<td>Studies pertaining specifically to Ethiopia are not yet available.</td>
</tr>
<tr>
<td></td>
<td>Possible respiratory effects, allergic airway air pollutants and changes in allergens due to climate change are suspected to worsen allergic disease and asthma.</td>
<td></td>
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<tr>
<td><strong>Vector Born Disease</strong></td>
<td>Likely to increase transmission seasons and geographic distribution.</td>
<td>Malaria, cholera, Dengue, parasites (STHs)</td>
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<td></td>
<td>Malaria will move to higher altitudes by 2050 (IPCC). Extreme weather events will exacerbate the problem.</td>
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<tr>
<td><strong>Zoonotic Diseases</strong></td>
<td>May alter vector dynamics, temporal/spatial distribution, and prevalence</td>
<td>Ethiopia identified as a “hot zone” region for zoonotic disease events (7)</td>
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<td></td>
<td>Disease transmission directly or indirectly via contaminated water, food, meat, milk etc. Flooding exacerbates the possibility of disease transmission.</td>
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</tr>
<tr>
<td><strong>Mental Health</strong></td>
<td>Likely to increase with traumatic climate events</td>
<td>Studies pertaining specifically to Ethiopia are not yet available.</td>
</tr>
<tr>
<td></td>
<td>Increase in stress disorders, substance abuse, suicide risk, anxiety, and depression.</td>
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