Review Article

Review of Climate Change and Health in Ethiopia: Status and Gap Analysis

Belay Simane[1], Hunachew Beyene[2], Wakgari Deressa[2], Abera Kumie[2], Kiros Berhane[3], Jonathan Samet[3]

Abstract

Background: This review assessed Ethiopia's existing situation on issues related to the environment, climate change and health, and identifies gaps and needs that can be addressed through research, training, and capacity building.

Methods: The research was conducted through a comprehensive review of available secondary data and interviewing key informants in various national organizations involved in climate change adaptation and mitigation activities.

Results: 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 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. Currently, research on climate change and health is not adequately developed in Ethiopia. Research and other activities appear to be fragmented and uncoordinated. As a result, very few spatially detailed and methodologically consistent studies have been made to assess the impact of climate in the country. There has often been a lack of sufficient collaboration among organizations on the planning and execution of climate change and health activities, and the lack of trained professionals who can perform climate change and health-related research activities at various levels.

Conclusion: Firstly, there is a lack of organized structure in the various organizations. Secondly, there is inadequate level of inter-sectoral collaboration and poor coordination and communication among different stakeholders. Thirdly, there are no reliable policy guidelines and programs among organizations, agencies and offices that target climate change and health. Fourth, the existing policies fail to consider the gender and community-related dimensions of climate change. Fifth, the monitoring and evaluation efforts exerted on climate change and health activities are not strong enough to address the climate change and health issues in the country.
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Introduction

Since the beginning of the industrial revolution, the global climate has been changing due to the carbon-intensive paths of development pursued by high-resource countries. The size of the human population and its impacts on the environment have increased dramatically over the last decades (1).

Climate change is of critical importance to Ethiopia. Mainly due to changes in the climate, Ethiopia has faced recurrent droughts across its different parts. This has been more observable particularly since the 1970s. The population size of Ethiopia and the impact of the activities of the growing population have increased dramatically over the last decades. There are frequent changes in the climate. These changes are often followed by droughts. Not only Ethiopia but many other African countries have also often fallen victim to these changes. Facing challenges associated with climate change has since recently become global trends. The mean annual temperature has, for example, increased by 1.3°C between the years 1960 and 2006. This is estimated to be an average rate of 0.28°C increase in temperature per decade (2, 3).

Human-induced climate change is feared to lead to unprecedented level of global warming in the next few decades. Climate models suggest that Ethiopia will see a further warming of 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s (4). The current population (over 87 million) is growing annually by 2.6% and is expected to be more than double by 2050 (5). The country is extremely vulnerable to the impacts of climate change. The impact may potentially hold back economic progress or reverse the gains made in development, and thus exacerbates social and economic challenges (6). The country's vulnerability to climate change is further increased by high levels of poverty, rapid population growth, and reliance on rain-fed agriculture. In addition, high levels of environmental degradation, chronic food insecurity, frequent natural drought cycles, etc. may also be other factors that can contribute to the country's vulnerability to climate change (3).

Recurrent droughts and floods in Ethiopia have resulted in loss of life and property as well as in the displacement of people. Drought frequency is predicted to increase, placing stress on already vulnerable food production systems. Rapid population growth and inappropriate traditional farming and management

[1]College of Development Studies, Addis Ababa University, Email: simaneb@yahoo.com or belay.simane@aau.edu.et, Ethiopia
[2]School of Public Health, College of Health Sciences, Addis Ababa University, Ethiopia
[3]Department of Preventive Medicine, Keck School of Medicine, University of Southern California, USA

practices put intense pressure on the country's soil, water and biodiversity resources. Extensive cultivation, overgrazing, deforestation, etc. are all instances of poor management practices. These all add to the national challenge of responding to climate change (7).

Climate change is predicted to reduce the gross domestic product (GDP) growth of the country by between 0.5 and 2.5% each year. The need for urgent and effective steps to build resilience are unquestionable (8). Climate change has the potential to hold back economic progress. Worse is that it can even reverse the gains made in the development and exacerbate social and economic problems in the country (3, 9).

Climate change is currently adversely impacting the health and lives of people around the world. This is particularly true in low-income countries (10, 11). It affects social and environmental determinants of health – clean air, safe drinking water, food security and shelter (12).There are several mechanisms through which climate change impacts health. However, two main climatic impacts on health are evident from the literature. The first one is the direct effect caused by heat stress and weather-related extreme events that result in increased morbidity and mortality. The other one is the indirect effect. The indirect effect of climate change is climate-mediated change seen in the incidence of infectious diseases and deaths. 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 are the other climatic effects. Yet, other adverse health impacts of climate change are caused by scarcity of water and natural disasters such as floods and droughts (13).

This vulnerability has spurred much policy debate in recent years. In this regard, it is important to mention that Ethiopia is has formally merged her aims of developing a green economy and building greater resilience to climate change under a single policy framework: the 2011 Climate Resilient Green Economy (CRGE) strategy. This initiative has a strategy for climate resilient development. This means that the strategy promotes green economy and seeks ways to improve the country's resilience to climate change. The strategy finds a means to reduce greenhouse gas and fosters both economic development and reduced carbon dependent growth (3). Thus, the country's green economy strategy leverages the financial opportunities and sustainability co-benefits of low emissions development. The climate resilient development strategy focuses on managing risk and building resilience to shocks through sequenced measures (3).

The aim of this paper is to assess the current situation and identify the gaps and needs related to climate change and its related effects on human health. An attempt was also made in the paper identify gaps and needs for which research, training, and capacity building projects can be developed in Ethiopia and in other Eastern African countries.

Methods

This paper is based on an extensive literature review related to climate change and health issues in the context of Ethiopia. In addition, relevant policy and program documents published by various key stakeholders were reviewed. Interviews were also held with key informants. Semi-structured questions were used during the interviews. The key informants considered in the interview were people who were responsible for managing and overseeing climate-related activities in various organizations.

Results

Climate Change in Ethiopia: There is considerable evidence to show the changing nature of the climate. Projections suggest that the rate of the change in climate will increase in the future in Ethiopia. Ethiopia's First National Communication (14) analyzed 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. Warming has occurred across much of Ethiopia, particularly since the 1970s at a variable rate. The change is broadly consistent with the change in wider African and global trends (Table 1). The mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade (2, 15). Daily temperature observations show increasing frequency of both hot days and hot nights. Climate models suggest that Ethiopia will see further warming in all seasons.

Table 1: **Ethiopia's changing climate**

	Mean Annual Temperature	Mean Annual Rainfall	Extreme weather events
1960-2006	• Mean annual temperature increased by 1.3°C from 1960 – 2006 • More hot days and nights, fewer cold days and nights	• Highly variable from season to season, year to year, decade to decade • No significant trend	• Regular severe flooding and drought events • No evidence of change in frequency or intensity of extremes
2020s	+ 1.2 °C (range: 0.7 – 2.3°C)	+0.4%	• Heavier rainfall events. • Uncertain future El Nino behavior brings large uncertainties • Flood and drought events likely to increase • Heat waves and higher evaporation
2050s	+ 2.2 °C (range: 1.4 – 2.9°C)	+1.1%	
2090s	+ 3.3 °C (range: 1.5 – 5.1°C)	Wetter conditions	

Source: *The Climate Resilient and Green Economy strategy of Ethiopia (CRGE) (3).*

While regional models predict increase in rainfall, higher resolution analyses for Ethiopia suggest spatial variations in which there are both increases and decreases in the overall rainfall averages. An increase in the rainfall variability is also predicted, with a rising frequency of both extreme flooding and droughts that could seriously affect agricultural production. Mean annual rainfall in Ethiopia is projected to increase, mainly as a result of increasing rainfall in the short rainy season (October to December) in southern Ethiopia. Projected changes in the April to June and July to September rainy seasons are mixed – the tendency is towards a small increase in the south (especially in the south-west) and a decrease in the north-east. The April to June and July to September rainy seasons affect large portions of Ethiopia.

It is also projected that the proportion of heavy precipitation events will increase throughout the country, especially during the July to September and October to December rainfall periods (9, 15, 16). Both the frequency and intensity of droughts in Ethiopia have increased recently and these have inflicted severe damage to the livelihood of millions of people. At the same time, increases in flood have stressed social institutions and intensified vulnerability of households.

High inter-annual rainfall variability has been observed in Ethiopia. In addition, some researchers have reported that rainfall has recently shown a downward trend in some parts of the country. This, however, is non-uniform; it varies by the region or the period used for analysis. For example, the Ethiopia Food Security Update (14 Aug 2003), reported a significantly decreasing trend of rainfall during the rainy season (kiremt) in the southwestern highlands of the country for the period 1961-1996 (17). Conway (2000) reported absence of any long-term trend for annual rainfall in the northern and north-eastern parts of the country. Conway et al. (2004) (18) 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 Sileshi and Zeleke(19). Sileshi and Zeleke 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. However, they (18, 19), found significant declines in the annual and kiremt rainfall totals in the eastern, southern and southwestern parts of Ethiopia.

Meze-Hausken (2004) (20)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. Apparently, the local people held this perception because of loss of spring rains (March-May, belg) and a shortened rainy season they experienced (kiremt). Bewket and Conway (21) analyzed rainfall in the Amhara region and concluded that the region had recovered in the 1990s from the dry phase that started in the 1980s. In fact, the rainfall levels in 2001-2003 were average or slightly lower than average. With intermittent dry years, rainfall in the central and northern highlands has recovered substantially since the 1980s.

Global climate models (GCM) provide the most reliable information on the characteristics of future climate change. The GCM experiment was designed to simulate future response of the climate system to increasing concentration of greenhouse gases globally. The results of GCM experiments are generally referred to as *scenarios*. Scenarios often comprise changes in temperature, rainfall, other climate variables and limited information about changes in extremes.

Results from several GCMs are used to represent the range of possible changes that may 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.(9), averaged the results from several GCMs and provided a guide to the overall direction of changes across all models, using 15 GCMs (an

'ensemble'). Values from the warmest/coolest and wettest/driest models were used to illustrate the range of uncertainty in the scenarios. The scenarios showed continued warming throughout Ethiopia.
The warming, as reported in the conclusion, is 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 can be associated with a greater frequency of heat wave events. Higher temperatures are likely to lead to higher rates of evaporation. If other influences remain unchanged, there will be higher rates of surface water evaporation and higher loss of moisture of the soil.

Extreme Events: Ethiopia has been experiencing climate extremes, such as droughts and floods, increased temperature, and erratic rainfall (22). Studies show that the frequency and magnitude of droughts has increased over the past few decades, especially in the lowland areas of the country (23). Drought occurrences have become endemic to the country (Figure 1) and are severely affecting the livelihood 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 these droughts have led to famines in addition to dozens of local droughts (24). The severe droughts resulted in the drying up of water sources, leading to serious water shortages. The resulting compromised personal hygiene can lead to escalated faeco-oral transmission of diseases (25).

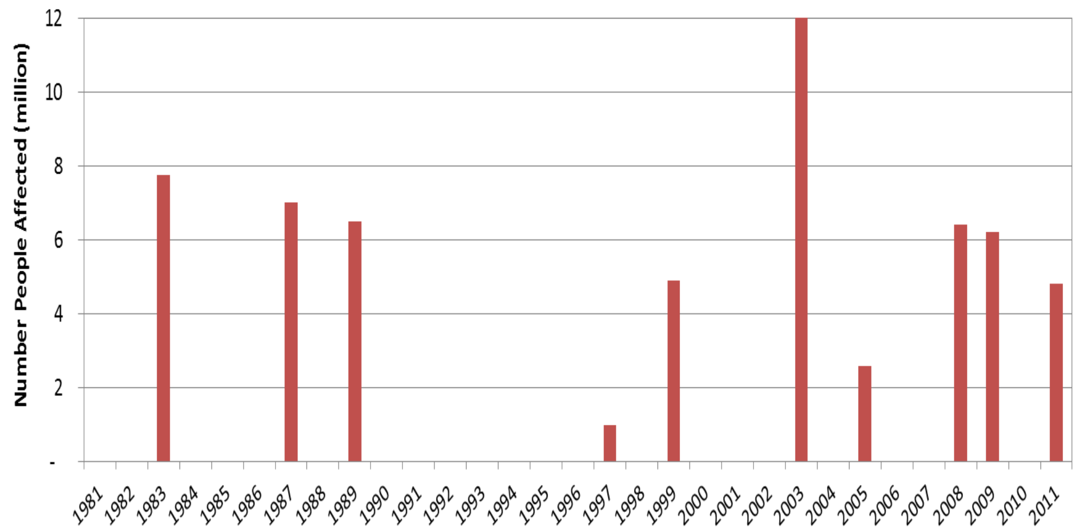

Figure 1: **Drought occurrences in Ethiopia for the period 1981 to 2011**
(Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be –Université Catholique de Louvain – Brussels – Belgium.Accessed May 19, 2010 (26)).

Drought and floods are predicted to become more and more severe under most climate change scenarios. Inter-annual climate variability, complex topography and associated local climate contrasts can be mentioned as factors that make drought and floods severe. In addition, erodible soils, unwise land-based activities of large population size and backward agricultural practices are among other factors that add to the severity of drought in Ethiopia (7). In 2015, close to 15 million people were staved due to El Niño-caused drought in Ethiopia. El Niño (EN), i.e., the increase in the surface temperature in the central and eastern equatorial Pacific Ocean – is believed to be the cause of extreme events like drought and flood. The 2015-2016 El Niño has thus far proven itself to be the worst disaster on record. It interacts with global climate change, where higher atmospheric temperatures, due to greenhouse gas emissions, lead to a higher frequency and greater intensity of the extreme weather.

The oceanic and atmospheric processes in another part of the world, such as the equatorial Pacific, could affect Ethiopian climate. Reliable ENSO information could be useful to forecast drought with a longer lead time. This enables policy-makers to introduce early mitigating policies.

Many areas of the country are prone to flood, which is the second most catastrophic natural disaster. An increase in the occurrence of flood adds stress to the local government's spending and increases the vulnerability of the households in Ethiopia (Figure 2). The major floods that occurred in 1988, between 1993-1996, and in 2006 resulted in considerable loss of lives and properties (22).

A recent study by Wakuma *et al.* assessed the flood risks and health-related issues in the Gambella region of the country. The study identified three critically important weaknesses, including a lack of flood-specific policy, absence of risk assessment, and weak institutional capacity (27). The 2008 flood that occurred in Gambella was one example of the increased frequency and magnitude of flooding in other parts of the country over the past decade.

Changes in land-use (i.e., deforestation and over cultivation) and climate change were considered to be the causes of the floods in Gabella. The presence of rivers such as the Baro, Akobo, Gilo, and Alwero and low lying homogeneous topography of the area were also factors that contributed to the floods in the area.

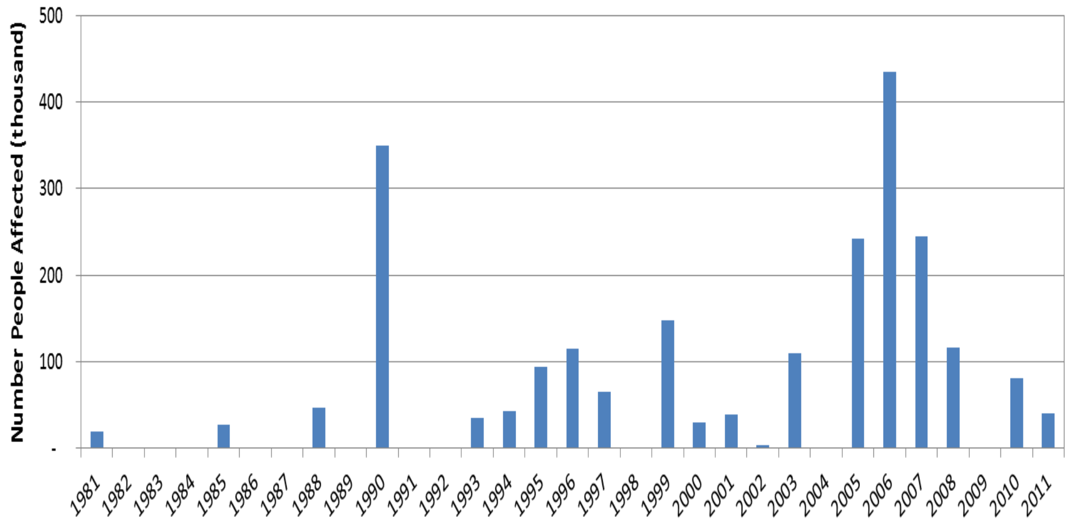

Figure 2: **Flood occurrences in Ethiopia for the period 1995 to 2007**
(Source: EM-DAT: The OFDA/CRED International Disaster Data base, www.emdat.be –Université Catholique de Louvain – Brussels – Belgium. Accessed May 19, 2010 (26).

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 rate in the country. The number of people suffering due to heat waves in the region is on the increase (28). Inadequacy of medical facilities and qualified and trained local personnel aggravates climate-related problems in the region (28).

Another study (2011) reported drought, erratic rainfall, animal diseases, shortage of water, and human diseases due to climate change to be the major hazards in Chifra wereda of the Afar Region (29). Trends are evident in the region not only of increasing temperatures and declining short rains, but also of unchecked population growth and rangeland degradation. A significantly decreasing herd size per household, an increase in basic infrastructure and incentives for settlement are also among the recent developments reported in the study carried out in the Afar Region (29).

The same report also found that there have been an increase in the temperature, a decrease in the rainfall, an extensive deforestation, a decrease in plot sizes of households, and a decrease in the availability of grazing land in the Gemechis district of Oromia Region (29).

In the Borana and Somali communities of Ethiopia, increased human health problems are already present due to high temperatures, increase in barren land, increased dust and wind, and scarcity in drinking water. Most of the natural, financial, human, and social resources on which Borana and Shinile communities depend are already badly affected by climate-related hazards (30). Higher temperatures and increased rainfall intensity may lead to flash floods that resulted, for example, in more water-borne diseases in Borana. On the other hand, a dry season with scorching heat in Shinile could change the distribution, range, prevalence, incidence, and seasonality of sanitation-related and vector-transmitted diseases (30).

Floods also damage crops and inundate farmland. This results in food shortages that may lead to malnutrition. For instance, the 2006 flood in the Gambella region damaged 1,650 hectares of maize crops (27). According to local reports, production was reduced by 20% mainly due to water logging on the farmlands. Most people affected by this flood were fell highly vulnerable to food insecurity. Without much doubt, one can state that a shortage in food can exacerbate the existing malnutrition in the country.

Climate-sensitive Diseases: According to the Ethiopian Climate Resilient Green Economy document, the health impacts of climate change will be manifested through morbidity and mortality caused due to extreme temperature. An increase in vector-borne diseases (e.g., malaria and bilharzias) and weather condition-related diseases (e.g., diarrhea and cholera) are also mentioned in the document as other examples of impacts of climate change. Not only these but also mentioned in the document are health problems due to poor air quality; mortality due to floods and storms, and malnutrition due to shortage of food and water supply (15).

Vector-borne Diseases: Climate change has played an important role in exacerbating malaria in the eastern African region. This implies that other factors previously suggested to explain the increase in the spread of malaria may be enhancing the impact of climate change (31). According to the World Health Organization (WHO), 68% of Ethiopians are living in areas at risk of malaria (24). Changes in climate are also likely to lengthen the transmission period of major vector-borne diseases and alter their geographic range. Climate change is projected to cause encroachment of malaria from lower altitudes in the Somalia and Afar to higher altitudes in the Tigray and the Amhara regions of Ethiopia (22). Tanser estimated a 5-7% potential altitudinal increase in malaria distribution. This means that malaria-free highlands in Ethiopia may experience the modest changes to malarial conditions by the 2050s. Conditions for malarial transmission in the highlands of the country are feared to become highly suitable by the 2080s (32).

Recently, WHO has confirmed that malaria, dengue fever, and yellow fever are the main vector-borne disease concerns of Ethiopia? It was also noted that there is a complicated relationship between climate change and climate-sensitive diseases, given climate variability between regions within Africa over time, and the impacts of the variability at the community-level (13).

Transmission of malaria is seasonal and unstable in Ethiopia, with September to December being the peak transmission season. This timing makes the magnitude of the problem higher as these are months of the major crop harvesting season. This places a significant economic burden on rural households and individuals both through increased out-of-pocket payments and person-days lost (33).

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). Monthly minimum and maximum temperatures and monthly total rainfall, considered as a one-month lagged effect, were significant meteorological factors for transmission of malaria in Jimma (35). A modeling study from Southern Ethiopia, *Falciparum* malaria incidence was linked to meteorological data (36). A positive association was found between malaria incidence and temperature in March, May, and the months between July and October. A positive association was also found between malaria incidence and rainfall from January to April and in the months of September and November in Southern Ethiopia. A pattern of dramatic decrease and increase in malaria cases before and after the peak rainy season in May was reported in the modeling study mentioned earlier (37).

Climate change-induced malaria has also been reported in the Afar region (28), and in South Omo. In both places the rate of flooding has increased and a large area has come under permanent flooding. This has triggered the infestation of bush and mosquitoes (malaria) (38). In Jimma town, during the last ten years (2000-2009), a fluctuating trend of malaria transmission was observed, with P. vivax becoming a predominant species. Spearman correlation analysis showed that monthly minimum temperature, total rainfall and two measures of relative humidity were positively related with malaria but monthly maximum temperature was negatively related. This indicates that malaria incidence in the last decade seems to have a significant association with meteorological variables (39). A recent study conducted in North-Western Ethiopia by Alemu et al. (2014) revealed that spatial clustering of malaria cases occurred at high elevation villages in North-Western Ethiopia (40).

Climate change is feared to expose an additional 2 billion people worldwide to dengue transmission by the 2080s (41). Dengue transmission is projected to significantly widen in the area where the snail-borne disease schistosomiasis occurs (42). On the other hand, visceral leishmaniasis (VL) has become a growing health problem in Ethiopia. The annual burden of VL is estimated to be between 4,500 and 5,000 cases. The population at risk is more than 3.2 million. Over the last decades, almost all cases and outbreaks of VL were reported from arid and semi-arid parts of Ethiopia. The collected evidence showed a growing change in the epidemiology of VL in the country. The 2010 WHO Ethiopia Country Office reported that, due to population movement, immune suppression (due to HIV/AIDS, malnutrition), and climate change, Leishmaniasis disease was observed to have spread to new localities in the country over the previous 5 years. Libo and Fogera in Amhara, Tahtay Adiabo in Tigray, and Imey in Somali regional states were among the new localities covered in the spread of the disease(43). More recent reports indicated that the introduction of this disease into the highlands might be linked with migration of laborers to and from endemic areas, climatic and environmental changes, and impaired immunity due to HIV/AIDS and malnutrition (44).

Water-borne Diseases: Several studies show that temperature, precipitation, and humidity have been among the most important determinants of diarrheal diseases 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. This means that rising water temperatures result in increased growth of bacteria in water (50), leading to increased rates of diarrheal diseases (51). Climate change-induced flood results in the disruption of drinking water sources. This leads to pollution, which in turn, increases the risk of exposure to water-borne pathogens. Water-borne pathogens cause water-borne diseases, especially diarrhea (52, 53). In another context, drought conditions associated with high evaporation rate can concentrate contaminants in smaller volumes of water and affect hygiene practices that control the spread of infectious diseases (54). A review reveals a trend for rotavirus to occur in the cool, dry seasons in tropical countries, as observed in temperate zones. These results suggest that paying close attention to local climatic conditions will improve our understanding of the transmission and the epidemiology of rotavirus disease (55).

In Ethiopia, only a few studies have examined the association between climate change and water-borne diseases. However, the available reports the studies released indicate possible linkages. Based on the recent Ethiopian Demography and Health Survey (EDHS) report, the prevalence of diarrhea varies seasonally (EDHS, 2011). An epidemic of cholera occurred following extreme floods in 2006, and led to widespread illness and loss of life (56). Outbreaks of acute watery diarrhea (57) have occurred in different parts of Ethiopia since 2006. This caused morbidity of thousands and mortality of hundreds of people (57).

Zoonotic Diseases: 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 (58). An estimated 75% of emerging infectious diseases in humans have evolved from exposure to zoonotic pathogens (59, 60). Climate change may cause increased environmental survival of pathogens. It may also cause changes in prevalence of pathogens in animal reservoirs, and changes in host–parasite ecology (61). Climate change could also shift boundaries for spatial distributions, host–parasite assemblages, and demographic rates. Life-cycle phenologies, associations within ecosystems, virulence, and patterns of infection and disease may also be caused by climate change (62).

Climatic variation also creates new ecological niches for vectors. It may also influence the epidemiology of zoonotic diseases, and causes changes in reservoir and vector dynamics (63, 64). Zoonotic infections are on the rise. The infections pose significant additional threats to human health (65). The threat gets worsened due to the complexity of the different organisms involved (66). In low-income countries, zoonoses are estimated to be responsible for one-fifths of the infectious diseases in human (67).

Ethiopia was identified as a "hotspot" for zoonotic disease events. The country ranked number one hotspot for leptospirosis, the fourth largest hotspot for Q fever and Trypanosomosis, and the tenth for tuberculosis. Much of the burden of zoonosis (68%) is distributed among only 13 countries. Ethiopia has the 4th highest burden caused by zoonosis (68). These data indicate an already existing burden of zoonotic disease in the country. The burden has the potential to be exacerbated by the effects of climate change. Researchers have identified an association between outbreaks of leptospirosis and extreme rainfall and flooding in a wide range of countries with different ecologies (69). Although only a limited number of studies have examined the effects of climate change and zoonotic disease in Ethiopia, the existing conditions seem suitable for the occurrence of climate-induced zoonotic disease. Ethiopia's large livestock population, in conjunction with predicted increases in both temperature and flooding and an established burden of diseases, suggests that climate change may greatly increase the incidences of leptospirosis in the country. In Wonji hospitals almost half of all patients tested for leptospirosis were positive (70).

Meningitis: The IPCC 4th assessment report indicated that climate change and variability have an impact on the epidemiology of meningitis. This is especially true in countries within the 'Meningitis Belt'. Countries within the meningitis belt experience the highest endemicity and epidemic frequency of meningococcal meningitis (71). Climate change intensifies the factors that determine meningitis outbreaks the most. Humidity (drought) and dust levels of areas that will become more arid are among the factors the determine meningitis outbreaks.

Several studies have addressed the seasonality of meningitis. Gessner et al. (2010) found that, similar to meningococcal meningitis, pneumococcal meningitis is seasonal, occurring primarily in the dry season (72). 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. The spatial distribution of the disease indicates the existence of a close linkage with climate change (73). Large epidemics occur during the dry season, between December and June, in the meningitis belt area (73). This pattern has been attributed to the effects of dust winds and upper respiratory tract infections caused by cold nights on the local immunity of the pharynx, 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. The relationships existed in all land-cover classes, but the strongest relationships were reported in savannah areas (74).

Recent analysis of reported epidemics indicated a southward shift in the distribution of epidemics over time. The distribution of the epidemics in the newly affected areas (i.e., south of the current meningitis belt) was found to be consistent with the changes in the region's climate/environment in many areas (75). Absolute humidity, dust and rainfall profiles, land-cover type, and population densities were associated with the location of the epidemics (76).

In Ethiopia, 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 occurrence affected almost 50,000 people (77).

The Southern Nations, Nationalities, and Peoples Region (SNNPR) and the Oromiya Region have been most severely affected in the past. The Amhara, Gambella, and Tigray regions also experienced significant impacts (78). Recent studies indicate an expansion of certain sero-groups of meningitis in Ethiopia beyond the areas traditionally included in the meningitis belt (79). This is mainly consistent with changes in the region's climate/environment in Southern Province in Ethiopia (75). A 2013 press release by the Federal Ministry of Health stated that a meningitis outbreak occurred in some parts of the SNNPR region of Ethiopia. Here, the outbreak often occurs during the dry season, particularly from December to June. The presence of dusty winds and respiratory infections characterizes this period in the region (80).

A recent retrospective study 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 were recorded in the dry months, April to June (81).

Nutrition-related Impacts: Climate change affects nutrition through various causal pathways that impact food security, sanitation, water and food safety, health, maternal and child health care practices. Climate change is feared to increase the risk of hunger and under-nutrition over the next few decades (82). According to the IPCCC, under-nutrition linked to extreme climatic events may be one of the most deadly consequences of climate change (6). A study which assessed the prevalence of rural and urban food energy deficiency in selected African countries showed that Ethiopia ranks the fourth among the worst food insecure countries in the sample considered in the study. The study was based on household data collected provided by Food and Agriculture Organization (FAO) (83). In addition, low agricultural yields and average farm sizes, land degradation and deforestation, and chronic problems with food security are often reported to characterize Ethiopia (84).

Recent reports on vulnerability mapping also confirmed Ethiopia's high vulnerability to climate change. It also has the least capacity to respond(9). The same study argues that climate change will be a major challenge to the country's efforts towards achieving food security and environmental sustainability.

Climate change is projected to reduce yields of the wheat staple crop by 33%, further contributing to poverty in Ethiopia (22). This will further aggravate the effects of the HIV pandemic. HIV pandemic reduces the workforce dedicated to agriculture and food supply (85). The threat becomes more serious when agriculture is considered to be the basis of the livelihood of the population affected by HIV. Climate change will also put a further strain on the already heavy workload of women. For example, the change will have negative impacts on women's ability to provide proper care to infants and young children. Obviously, this increases the risk of under-nutrition (85). 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 their birth happens to be in a drought season. For Ethiopia, these estimates could be translated into having about 2 million additionally malnourished children in 2005 (56).

In areas of Ethiopia where drought is more frequent, such as Shinile and Borena, pasture and water scarcity is leading to low conception rates and poor health of lactating animals. This has an undesirable implication for the availability of milk and milk products for home consumption (30). It has been concluded that, unless pastoralists switch to better-adapted livestock species, higher temperatures and increased rainfall unpredictability, combined with increasing land degradation and bush encroachment, will result in increased food insecurity and nutritional deficits.

The impact of food insecurity and malnutrition is more severe on poor households that have no financial capacity to modify their herd composition (30). In Afar, food insecurity, malnutrition, and poor child growth and development are among the indirect impacts of climate change-related exposure on human health (28). A longitudinal panel study on 43 clusters (administrative zones) used crop productions (cereals and oilseeds), livestock, monthly rainfall and temperature, and child under nutrition data for the period of 1996, 1998, 2000 and 2004 reported a spatio-temporal variability of rainfall, stunting and underweight. The study concluded that rainfall and temperature are partly predicting the variation in child stunting and underweight (86). Data obtained through 145 observations were among the data used in the study.

Gap and Needs Analysis: This review shows that much has been accomplished. There is a significant level of recognition about the effect of climate change among higher government officials. The government 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). However, climate change-related health outcomes have not been sufficiently studied in Ethiopia to guide the development and implementation of adaptation and mitigation strategies. The main gaps identified affecting the CRGE implementation are the following.

Organizational Gaps: There is very little or no defined structure in the regional branch offices of the EPA. Also, the merging of the EPA and regional land administration offices does not seem to be helpful enough. Similarly, there a lack of inter-sectoral collaboration among the organizations that works on climate change-related activities. Furthermore, the connection between the National Meteorology Agency, the Ministry of Health, and the Ministry of Agriculture and academic and research institutes has been found inadequate.

Admittedly, the impact of climate change has been identified by various organizations. Yet, there are no strong specific units in each institution that can lead and organize climate change-related activities. Another gap observed is related to the fact that on the one hand, the Public Health Emergency Management (PHEM) at the MOH is responsible for 24 reportable diseases with potential outbreaks related to climate change, while on the other hand, the regional health bureaus are not self-sufficient to handle the outbreaks. They usually expect a national-level response for such problems.

The coordination and communication activities that prevail among the various stakeholders on climate change and health leave much to be desired yet. In addition, the involvement of the private sector in the endeavors of climate change and health is highly limited.

It is important that organized structures be found between the regional branch offices. The need to strengthen inter-sectoral collaboration among the organizations working on climate change-related activities is equally pressing. Not less urgent is the need to design a reliable channel that ensures communication and exchange of information among different stakeholders on climate change and health.

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 on sufficient evidence that is specific to Ethiopia. There is a lack of research capacity among experts, and equipment limitations to carry out research linked to climate change.

In addition, there is a lack of baseline data on basic climate change indicators, e.g., carbon release of the industrial sector. There is also a lack of laboratories and research funds to carry out climate change and health-related research. There is no specific training that may enhance the research activities, e.g., climate change modeling and longitudinal data analysis, are lacking.

What is urgently needed is establishing climate change and health research centers that have laboratories and baseline data to carry out research on climate change and health.

Training Gaps: The staff members who are currently working on climate change and related outcomes in the various organizations are inadequately trained in the techniques that are specifically related to climate change and health. Short and long-term training on climate change and health related sciences such as carbon trade negotiation, geospatial analysis, and hazard mapping needs in the area. Improving incentives and salary for the experts, promoting awareness among the community about climate change and health issues, developing curricula on climate change and health in both the under graduate and postgraduate programs are other priorities identified in this review.

Institutional Capacity: There is a serious lack of technologies that fit the local setting as well as a shortage of capital to adapt existing technologies. The MOA has identified climate change as a threat to development. The impact has become evident, with the changing pattern of rainfall in the last 3-4 decades. Recurring droughts have resulted in the reduction of GDP. The CRGE strategy was designed in 2011 in response to this. Initially, a case team was formed to coordinate activities related to the strategy. However, it has not been carried out due to a lack of collective vision and the high costs of 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 also a lack of trained personnel and experts on climate change and health in the organizations and between regional offices. Academic and research institutes are also said to be barely connected to the offices working in the area of climate change and health.

Multidisciplinary approaches among the professionals of health, agriculture, climate, and water resources are weak. Their activities are fragmented and their output is very insignificant. Also, an inefficient procurement system exists in most 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 Ministry of Environment, Forest and Climate Change (MEF) to implement and realize plans and strategies. Even if the funds were available, the absorptive capacity in some organizations may pose a problem.

We anticipate mobilization of adequate financial resources to properly implement climate change and health activities. However, international sources like Adaptation Funds, Carbon Markets and the Clean Development Mechanism (CDM) may not deliver the financial flows necessary to meet all climate change mitigation and adaptation needs of Ethiopia. It is therefore important to explore other innovative sources of local finance such as carbon tax. The CRGE Facility, launched in September 2012, is responsible for attracting, allocating and channeling international climate finance. The Facility is planning to leverage both public and private finance from multilateral and bilateral sources. Ideally, climate finance will complement other forms of investment to bolster Ethiopia's core climate-compatible development activities. Climate-compatible development activities include food security, energy, infrastructure development and natural resources management.

Policy Gaps: While policies and proclamations on climate change exist, those that connect climate change and health are lacking, and those that do exist are not up-to-date. In addition, 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, to the stakeholders, and to the pertinent organizations. The policies and the strategies are adapted mainly from international evidence and not from findings related to the local climate change and health. Climate change was not recognized as a public health threat in the 1993 health policy of the country. Not only this, but the existing policies also do not address the gender dimensions of climate change.

Monitoring and Evaluation: Proper monitoring and on-going evaluation of the climate change situation and its impacts are not in place. The data on climate change sensitive diseases and other health outcomes are not aligned with climate change. This calls for the need for multiple monitoring and evaluation mechanisms. Establishing and strengthening proper monitoring and evaluation systems on climate change and health at various levels in the organizations is another point in the priority list. Super computers are needed for climate and health data management and processing activities. Needless to say, working towards aligning climate data with health data, publishing climate change and health information as well as establishing websites for the wider dissemination of information are all immediate necessities. Additionally there is a need for establishing and strengthening 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 developing specific actions and responses needed to mitigate its consequences need yet further and harder work. Some impacts of climate change observed so far in the country are recurrent drought, flood, malnutrition, extreme heat and cold, and the re-emergence of climate-sensitive infectious diseases.

The impact of climate change is also reflected in increased environmental survival of pathogens and the creation of new ecological niches for vectors. This means a change is emerging in 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. Currently, research on climate change and health is at a rudimentary stage. This means that research findings and other activities tend to appear largely through fragmented. As a result, no spatially detailed, methodologically consistent climate impact studies are available in the country.

Poor collaboration is identified among various organizations in planning and executing activities related to climate change and health. This points 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. Irregularity in the rainfall leads to inadequate outputs of rain-fed agriculture, and this, eventually leads to food insecurity and malnutrition in the country.

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. Also, multidisciplinary approaches among professionals in the fields of health, agriculture, climate, and water resources are weak. This leads to fragmented activities with minimal output. The structures in the various organizations appear not to be sufficiently organized. The inter-sectoral collaboration among the organizations to work together leaves much to be desired yet.

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. This means that local climate change and health-related evidence do not seem to have been considered. There is 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.

Recommendations

There is a need for increasing community awareness and knowledge on climate change and health. This can be done through proper media and dissemination forums. Increasing the number of trained personnel in climate change and health at the higher learning institutions and research organizations is needed. Strengthening the research capacity on climate change and health is a desirable step to be taken. This can partly be done through training and providing technical support to academic and research institutes.

Establishing climate change and health research centers equipped with adequate laboratory facilities, and developing and strengthening national and international research collaborations are other essential areas. The existing policies need to be up-dated. This, in addition to the need to develop new policies and strategies that meet the current international and national standards, seem to be equally pressing issues. Similarly, there is an urgent need to mainstream climate change and health units at various organizations and academic/research institutes. These are, in short, the main priority needs identified in this review. Needless to say, all require the concerted efforts of stakeholders.

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