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Climate change in Ethiopia: impacts, mitigation and adaptation

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ABSTRACT

This review highlights climate change and its drivers, impacts, and mitigation and adaptation options in Ethiopia. Both climate variability and change have been occurring in Ethiopia. Evidences show that since 1960 the mean annual temperature of the country has risen by about 1.3°C, an average rate of 0.28°C per decade, and spatial and temporal rainfall variability has been increasing. As such, Ethiopia has been experiencing the impacts of both climate variability and change. Climate change has led to recurrent droughts and famines, flooding, expansion of desertification, loss of wetlands, loss of biodiversity, decline in agricultural production and productivity, shortage of water, and increased incidence of pests and diseases such as spread of cereal stemborers and malaria to higher elevation areas. On the other hand, Ethiopia has shown both conservation and policy responses to combat climate change. Protected area systems, afforestation and reforestation programmes, renewable energy sources and energy efficiency, ecological agriculture, flexible livestock production, homegardens and traditional agroforestry systems, harvesting and use/marketing of non-timber forest products and climate change education, are all feasible strategies for mitigating and adapting climate change. Indeed, there is a need to employ the right mix of climate change mitigation and adaptation strategies prioritized in space and time so as to reduce vulnerability of biodiversity and humanity to the escalating impacts of climate change. To this end, capacity building should be a priority. Moreover, there is a need to collaborate with the international community to combat climate change, which is a global challenge.

INTRODUCTION

The Earth's climate is rapidly changing as a result of increases in the concentrations of greenhouse gases (GHGs) in the atmosphere mainly caused by human activities, particularly burning of fossil fuels, agriculture and deforestation (Wigley, 1999; Stern, 2006; IPCC, 2007; Zegeye, 2013). The major GHGs responsible for climate change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Carbon dioxide is one of the primary causes of climate change due to the amount present in the atmosphere. Although molecules of methane, nitrous oxide and CFCs trap much more heat per molecule than carbon dioxide, the larger input of carbon dioxide makes it the single most important greenhouse gas produced by human activities. Electricity and heat production account for 25% of the GHG emissions; agriculture, forestry and other land uses (AFOLU) 24%; industry 21%; transport 14%; buildings 6.4%; and other energy 9.6% (IPCC, 2014).

Scientists believe that the global average surface temperature has risen over the past century. Since 1900, the global average surface temperature has risen by 0.76°C (IPCC, 2007; Deeb et al., 2011). The Intergovernmental Panel on Climate Change (IPCC) asserts that continued emissions of GHGs at or above

Figure 1. Map showing location of Ethiopia.

the current rates would cause an increase in the global average surface temperature by 1.8 to 4.0°C by 2100 (IPCC, 2007). On the other hand, precipitation has showed different spatial and temporal patterns (increases or decreases) in different regions of the world. Northern latitudes will experience more rainfall; many subtropical regions will see less (IPCC, 2001). Climate change will have significant impacts on natural and human systems.

Climate change has become a reality, and is one of the greatest challenges the world is facing today. Climate change has led to increased frequency and intensity/ severity of extreme weather events (droughts, floods, heat waves, cold snaps, storms/hurricanes, etc.), melting of ice and glaciers, sea level rise, changes in global precipitation patterns, expansion of desertification, increased frequency and intensity of wildfires, loss of biodiversity, increased environmental pollution, decline in agricultural production and productivity, water scarcity, increased incidence of pests and diseases, and human migration and conflict (Stern, 2006; IPCC, 2007; Zegeye, 2013). The impacts of climate change are global in scope and unprecedented in scale. The environment and humanity have been threatened by the escalating impacts of climate change (Zegeye, 2013). Thus, urgent actions are needed to combat climate change. Climate change is a truly global problem and thus requires a global solution. It is imperative that we need to think globally and act locally.

Ethiopia is located in the Horn of Africa, stretching from 3-15° N and 33-48° E and covering a total land area of 1.12 million km^2 (Figure 1). It shares borders with Eritrea in the north and northeast, Djibouti and Somalia in the east, Kenya in the south, and Sudan and South Sudan in the West. Ethiopia has great geographical diversity, and is mostly mountainous. The altitude of Ethiopia ranges from 125 m below sea level at the Danakil/Afar Depression (the lowest point) to 4,620 m above sea level at Mt. Ras Dashen/Dejen (the highest peak). The climate varies greatly from hot and arid in the lowlands to cool and temperate in the highlands. The mean annual temperature is from 17-29°C in the lowlands and 11-20°C in the highlands. The mean annual rainfall is 1,400–2,500 mm in the south and west, 1,050–1,200 mm in the central highlands, 400–2,000 mm in the southeast and 350-700 mm in the north (Teketay, 1999, 2004).

Ethiopia's climate is naturally both highly diverse and highly variable. However, the climate is dramatically changing in recent years (Umer, 2010; Eshetu, 2011; Mokria et al., 2017). Both climate variability and change have been occurring in Ethiopia. The temperature (maximum, minimum, mean) is increasing, but the rainfall does not show any definite trend– it shows high variability (NMSA, 2007; Bewket and Conway, 2007; McSweeney et al., 2008; Umer, 2010; Bewket, 2011; Eshetu, 2011; Addisu et al., 2015; Mokria et al., 2017). Since 1950, the annual average maximum and minimum temperatures of the country have been increasing every decade by about 1 and 0.25°C, respectively (NMSA, 2001). The mean

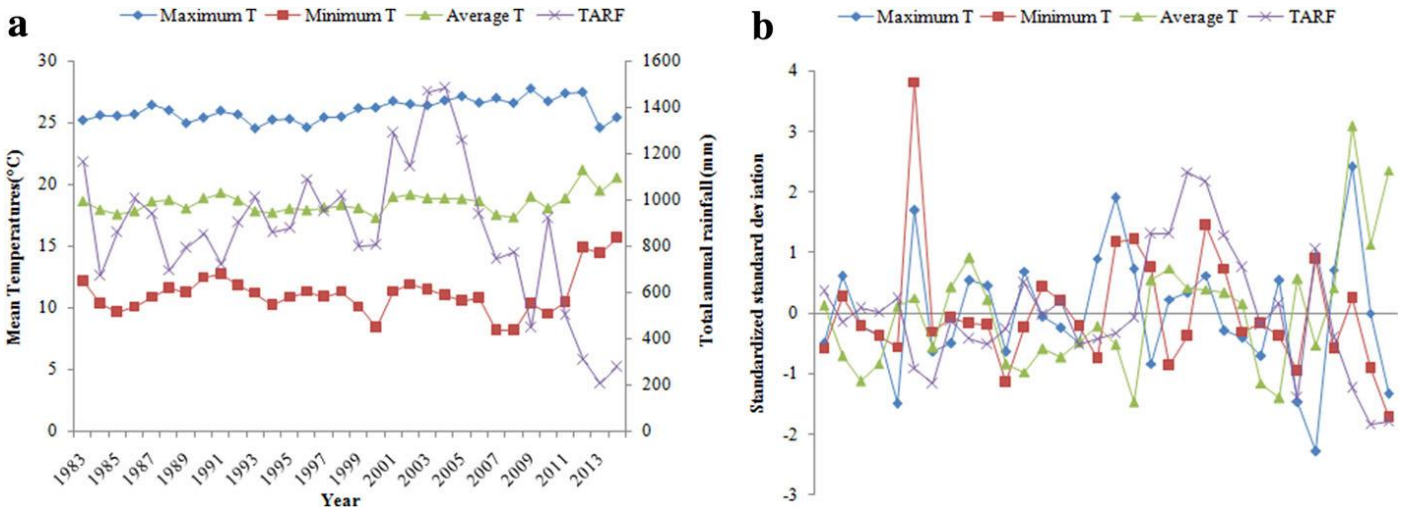

Figure 2. Temperature and rainfall trends (a) and their respective standardized anomalies (b) in Arsi Negele District.
Source: Mekonnen et al. (2017).

annual temperature for the period 1960-2006 increased by 1.3°C, an average rate of 0.28°C per decade (McSweeney et al., 2008). The decadal increase is above the global mean value of 0.2°C per decade (Hansen et al., 2006).

Spatial and temporal rainfall variability has been increasing. The length of the rainy season(s) and the reliability/predictability of the rainfall amount, frequency, distribution and timing (onset and ending) are decreasing. Reconstructed rainfall since 1811 revealed significant interannual variations between 2.2 and 3.8 year periodicity, with significant decadal and multidecadal variations during 1855–1900 and 1960–1990; the duration of negative and positive rainfall anomalies varied between 1–7 years and 1–8 years (Mokria et al., 2017). Analysis of the 40 years (from 1961–2013) annual total rainfall data from 109 representative ground-based meteorological stations in Ethiopia indicated a coefficient of variation ranging from 20 to 89%, and 17 stations had above 42% coefficient of variation highlighting the extreme variability of rainfall over the country (Addisu et al., 2015). Their result also showed that the maximum, minimum and mean temperatures had a general increasing trend; whereas rainfall amount showed a general decreasing trend in Lake Tana Sub-Basin. The annual rainfall amount of Menz Gera Midir District, North Shewa Zone of Amhara region varied over the years from 1974–2003: 1,500 mm (1977), 1,460 mm (1980/1981), 352 mm (1984, during the time of severe drought), 1,014 mm (1996), 1,050 mm (1998), 1,132 mm (2001) and 1,027 mm (2006), with declining trend over the three decades (Kassa, 2013). The annual mean maximum temperature, annual mean minimum temperature and annual mean temperature of Arsi Negele District, West Arsi Zone of Oromia region showed increasing trend; and the total annual rainfall (TARF) showed variation over the years from 1983–2014 with the peak in 2004 (1,486.5 mm) and sharp drop in 2013 (206 mm) (Figure 2). The amount of rainfall has been decreasing in many areas of the country, but increasing in some areas. For example, some areas in western part of the country have experienced irregularities, unpredictability and a pattern of shortened rains, temperature increase, heavy rains, frost and hail (Troeger, 2010).

Climate change projections for Ethiopia showed that, compared to the 1961-1990 normal, mean annual temperature will increase in the range of 0.9–1.1°C by 2030, 1.7–2.1°C by 2050 and 2.7–3.4°C by 2080, and a small increase in annual precipitation will occur over the country, with an increase of 1.3–6.1% by 2030, 2.4–11.6% by 2050 and 3.9–18.9% by 2080 (IPCC, 2007; McSweeney et al., 2008).

Climate change and its impacts have also been perceived by local people, who express (from their indigenous knowledge and experiences) climate variability and change in that generally the temperature is increasing and the rainfall is decreasing (Deressa et al., 2008; Bryan et al., 2009; Riché et al., 2010; Troeger, 2010; Kassa, 2013; Addisu et al., 2016; Belay et al., 2017; Mekonnen et al., 2017; Tilahun et al., 2017). The majority of local people in many areas have the perception that rainfall is just decreasing, but scientific evidence (analysis of rainfall data obtained from the meteorological stations) shows rainfall variability (decreasing; increasing; unpredictable frequency, distribution, duration and timing) depending on location

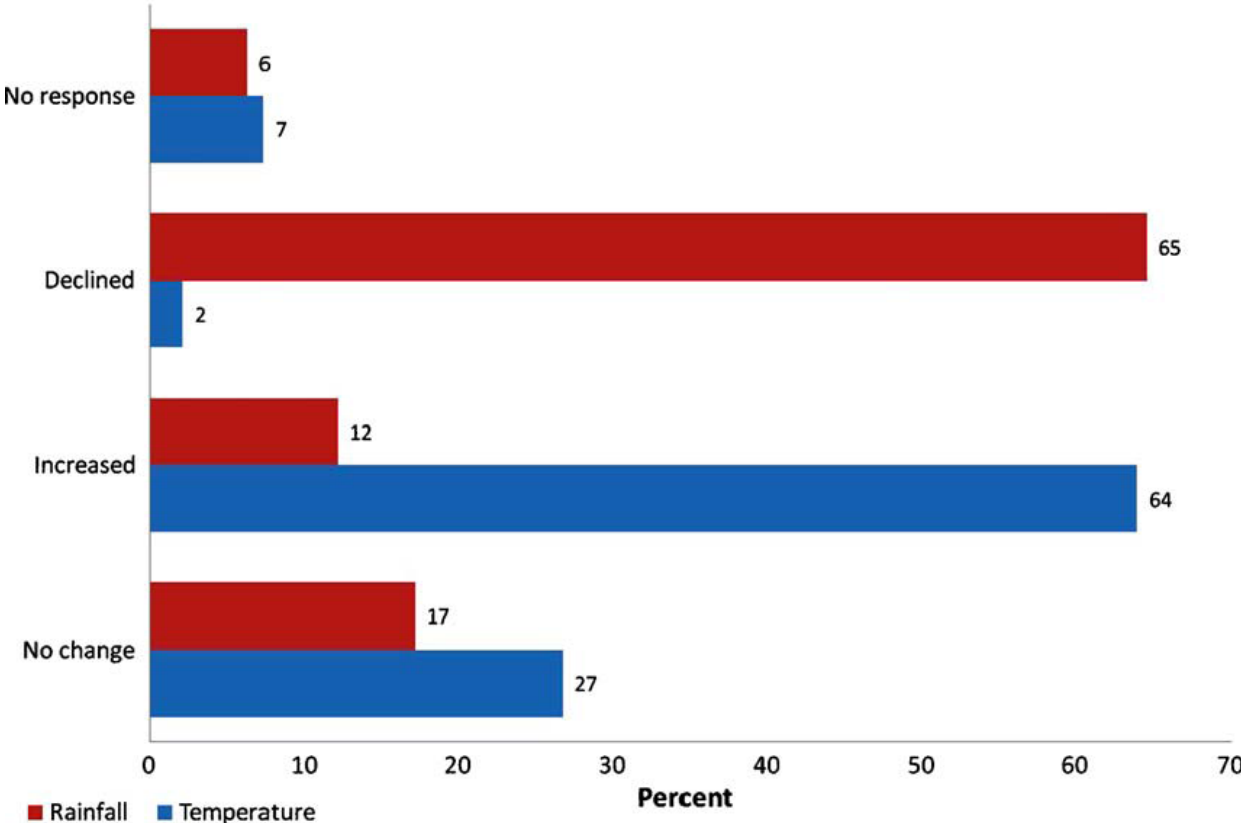

Figure 3. Farmers' perceptions of average temperature and rainfall changes in Ethiopia over the last 20 years from 2004/2005 (n = 1000).
Source: Bryan et al. (2009).

and time (season, year). Figure 3 shows farmers' perceptions of average temperature and rainfall changes in Ethiopia over the last 20 years from 2004/2005. On the other hand, the majority of people believe that climate change is caused by human activities such as deforestation, while some link it to supernatural wrath and punishment from God to the bad activities being done by human beings (Troeger, 2010; Kassa, 2013).

The frequency of droughts in Ethiopia, particularly in the recent decades, is an indication of the prevalence of the variation in climate. There were 19 drought events which occurred in Ethiopia in the period 1900–2002, which is almost once in 6 years in the period 1900–1987 (14 drought events) and roughly in 3 years in the period 1988–2002 (5 drought events) (NMSA, 1987; World Bank, 2005). Since 1876, about 22 droughts with an average cycle of every 6 years are occurring in Ethiopia (Eshetu et al., 2010). The frequency and magnitude of droughts in Ethiopia have been increasing in space and time.

Until very recently, studies on climate change in Ethiopia were very limited. Nowadays, research on climate change is expanding in Ethiopia (Eshetu, 2011). As such, the number of studies on climate change and its impacts is increasing and the major aspects addressed include: temperature and rainfall trend analysis, perceptions of local people, impacts on the environment and human society, vulnerability, and mitigation and adaptation strategies (Bewket and Conway, 2007; McSweeney et al., 2008; Deressa et al., 2008, 2009, 2011; Bryan et al., 2009; Riché et al., 2010; Troeger, 2010; Umer, 2010; Eshetu, 2011; Tesso et al., 2012; Gebrehiwot and van der Veen, 2013; Kassa, 2013; Addisu et al., 2015, 2016; Alemayehu and Bewket, 2016; Muluneh et al., 2016; Simane et al., 2016; Teshome, 2016; Tilahun et al., 2016; Belay et al., 2017; Mekonnen et al., 2017; Mokria et al., 2017). On the other hand, studies on specific aspects of climate change for localities are relatively many, whereas comprehensive studies on Ethiopia are still limited. Furthermore, research on the impacts of climate change in Ethiopia has been focusing more in the lowland parts of the country that is inhabited by pastoral communities and there has been limited understanding of the situation in the highlands agroecology (Kassa, 2013). This review tries to highlight climate change and its drivers, impacts,

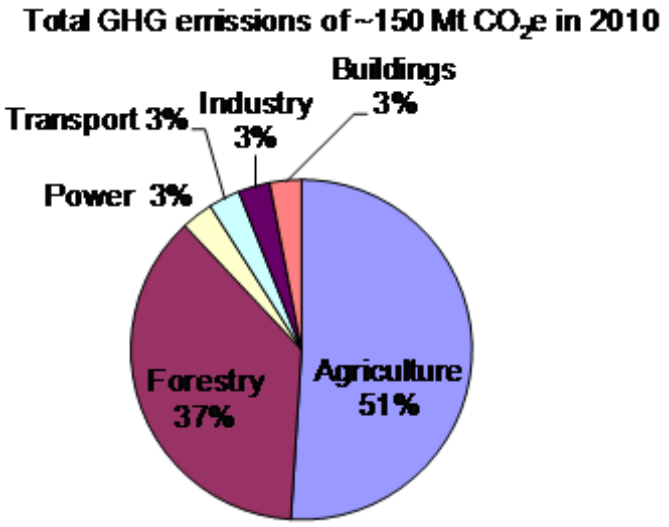

Figure 4. Share of different sectors in GHG emissions in terms of CO_2e in 2010.
Source: Modified from Anonymous (2011).

and mitigation and adaptation strategies/practices in Ethiopia.

ETHIOPIA'S CONTRIBUTION TO GLOBAL GREENHOUSE GAS (GHG) EMISSIONS

Ethiopia's current contribution to the global increase in GHG emissions is insignificant. Ethiopia's GHG emissions were estimated to be 150 Mt CO_2 equivalent (CO_2e) in 2010, representing less than 0.3% of the global emissions (Anonymous, 2011). Today's per capita emissions of less than 2 t CO_2e are modest compared with the more than 10 t per capita on average in the European Union (EU) and more than 20 t per capita in USA and Australia. Although the amount is very negligible when compared to emissions released by developed countries, it is expected to reach 400 Mt CO_2e by 2030 if the Climate-Resilient Green Economy (CRGE) strategy is not implemented. Of the 150 Mt CO_2e in 2010, 51% of the GHG emissions came from agriculture, 37% from forestry (includes deforestation), 3% from power, 3% from transport, 3% from industry and 3% from buildings (Figure 4). Thus, about 88% of the GHG emissions in Ethiopia come from agriculture and forestry. Deforestation is a strong contributor to climate change (Zegeye, 2017).

VULNERABILITY TO CLIMATE CHANGE

Ethiopia is a country with a very low carbon emission because of low industrial development, but will be among the countries the hardest hit by the impacts of climate change. Ethiopia is one of the most vulnerable countries in the world to the impacts of climate change and with the least capacity to respond (Stern, 2006; Thornton et al., 2006; IPCC, 2007; Zegeye, 2013, 2017). Studies indicate that smallholder farmers in Ethiopia are generally highly vulnerable to the impacts of climate variability and change (Deressa et al., 2008; Tesso et al., 2012; Gebrehiwot and van der Veen, 2013; Alemayehu and Bewket, 2016; Simane et al., 2016; Teshome, 2016; Belay et al., 2017). Ethiopia is vulnerable to the impacts of climate change mainly due to geographical location, rapid human population growth, heavy dependence on agriculture and natural resources for subsistence, widespread poverty and limited resources (human, financial, technical, technological, institutional, and infrastructural). Indeed, vulnerability to the impacts of climate change and the adaptive capacity of communities show regional variations because of the high diversity of agroecologies, cultures, production systems and livelihood strategies. Ethiopia has in general low adaptive capacity to the impacts of climate change. This implies that improving adaptive capacity is important in order to reduce vulnerability to the impacts of climate change.

IMPACTS OF CLIMATE CHANGE

Ethiopia is experiencing the impacts of both climate variability and change. Climate change has led to recurrent droughts and famines, flooding, expansion of desertification, loss of wetlands, loss of biodiversity, decline in agricultural production and productivity, scarcity of water, and increased incidence of pests and diseases. Climate change is likely to aggravate environmental degradation, food insecurity, water scarcity, disease epidemics and poverty in Ethiopia.

Environmental impacts

Extreme weather events

Climate change will increase the frequency and intensity of extreme weather events (droughts, floods, heat waves, heavy rainstorms, strong winds, etc.). Recurrent droughts have been experienced in the recent past, and are also presently occurring in many parts of the country. The severe drought that occurred in 1984/1985 is one of the most serious drought events experienced in Ethiopia, still persisting in the minds of many. The magnitude of droughts has been increasing in space and time. Droughts have historically been the immediate causes of food shortages and famines in Ethiopia. Recurrent droughts have resulted in loss of human and livestock life and property as well as migration of people (Eshetu, 2011; Zerga and Gebeyehu, 2016). The Afar region has

been known for its frequent droughts, which is the major appraised risk for decades (Tilahun et al., 2017). In Menz Gera Midir District (a highland area), recurrent droughts have occurred, with serious drought occurrences in 1984/1985, 1990 and 2000/2001 that caused many people to suffer and livestock to perish (Kassa, 2013). Floods have not been major problems in Ethiopia, but have become critical in recent years. For example, in 2006 the eastern and southwestern parts of the country experienced one of the most devastating floods in the modern history of the country (Bewket, 2011). The recent catastrophic floods in Dire Dawa, Awash, South Omo (Dasenech and Nyangatom Districts) and some areas in Somali and Amhara regions can be mentioned. In Dire Dawa, for example, the flood claimed over 256 lives and displaced more than 5,500 people; and also damaged property worth of ETB50 million, including major or total damage to 1,000 houses in the flood-prone areas of the town (Tadesse, 2009). Heavy rainstorms (thus floods) will aggravate soil erosion. Flooding in turn causes significant damage to settlements and infrastructure, animal health, and the waterlogging of productive land undermines agriculture by delaying planting, reducing yields, and compromising the quality of crops, especially if the rains occur around harvest time (World Bank, 2011). In the period 1999–2008, droughts and flooding affected nearly 21 million people (19.7 million by droughts and the remaining by flooding) in Ethiopia (CRED, 2009). Furthermore, climate models show warming in all four seasons over Ethiopia, which may result in more frequent heat waves (ODI and CDKN, 2014).

Expansion of desertification

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as the degradation of lands in arid, semi-arid and dry sub-humid zones following various factors among which climatic variations and human activities. A major impact of desertification is reduced biodiversity and diminished productive capacity. A large part of Ethiopia (ca. 70%) is arid and semi-arid (NMSA, 2007). Desertification is likely to expand in Ethiopia due to climate variability and change compounded with the prevalent deforestation. Most of the drylands, particularly in Afar, Somali, Borana and South Omo, are vulnerable to expansion of desertification.

Loss of wetlands

Ethiopia has numerous wetlands (streams, rivers, lakes, dams, ponds, swamps, marshes, etc.). However, many wetlands are facing serious ecological problems due to deleterious anthropogenic activities. Clearing of forests, construction of irrigation and drainage systems, building of factories and use of fertilizers and pesticides, all contribute towards the damage of these indispensable but fragile systems (Woldu, 2003). Water pumping for domestic, industrial and agricultural/irrigation purposes; sedimentation (resulting from poor agricultural practices, deforestation and overgrazing); construction of dams; overfishing; discharge of domestic and industrial wastes and excessive use of agrochemicals (pollution); and climate change, are all threatening wetlands. Deforestation, overgrazing, siltation and climate change have led to significant reduction in water level (volume and surface area) to complete drying up of many streams, rivers, ponds as well as lakes. Many lakes such as Tana, Ziway, Langano, Abijata and Chamo are shrinking in water level (but some lakes like Beseka/Metehara, Hawassa and Abaya are increasing in water level) (Lemma, 2003; Dejen, 2013; Wondie, 2013; Bewketu and Ayenew, 2016; Zegeye, 2017), and a few lakes have already dried up. Drying up of Lake Haramaya (formerly Lake Alemaya) is a very recent history (Lemma, 2003; Zegeye, 2013, 2017). Loss or degradation of wetlands will result in scarcity of water, loss of wetland biodiversity and associated livelihoods of people, and disruption of ecological systems in the area and beyond.

Impacts on biodiversity

In Ethiopia, many species are vulnerable to the impacts of climate change. Many forest tree species have showed hampered or poor regeneration due to human disturbances and changing environmental conditions including climate change. Dieback of *Juniperus procera* and *Olea europaea* subsp. *cuspidata* has occurred in Desa'a forest in Northern Ethiopia due to climate change (Aynekulu et al., 2011). Species with limited geographical opportunities, restricted habitat requirements and/or small populations (for example, species restricted to Afroalpine ecosystems, such as Giant Lobelia, Walia Ibex, Ethiopian Wolf) are typically the most vulnerable (Zerga and Gebeyehu, 2016). Environmental degradation and climate change will increase the spread and abundance of invasive alien species such as *Parthenium hysterophorus* and *Prosopis juliflora*, which are becoming threats to biodiversity of the country (Tadesse, 2001; Berhanu and Tesfaye, 2006; Zegeye, 2017; Sharma and Nigatu, 2013). Furthermore, climate change will cause shifts in the distribution of species and ecosystems. A climate model for Southwest Ethiopia predicted that biodiversity of the area will suffer severe consequences of lowland biotic attrition (that is, the net loss of species richness in the tropical lowlands caused by altitudinal range shifts in the absence of new species arriving), range-gap shifts and contractions, and extinction due to expected warming at the end of this century (Wana, 2009). The model also predicted that endangered and

endemic species with restricted elevational ranges will disproportionately suffer from range contraction and extinction due to warming.

Socio-economic impacts

Impacts on agriculture and food security

Ethiopia's agriculture is mainly rainfed. However, the traditional/subsistence rainfed agriculture is highly vulnerable to the impacts of climate variability and change, particularly droughts, which occur due to increased temperature and reduced rainfall in a given year and cause human suffering. Climate change causes more erratic rainfall (both in amount and distribution), increased soil erosion (due to heavy rains), shifts in sowing and harvesting dates of crops (delayed onset and early ending of rainfall), changes in agricultural systems and increased incidence of pests and diseases. It affects crop production, including staple crops such as wheat and maize and cash crops such as coffee, leading to poor harvests and/or complete crop failures. It is likely to affect crop yields negatively and therefore food security (Muluneh et al., 2016). In Menz Gera Midir District, indigenous varieties of wheat and barley are disappearing because of the recurrent droughts in the area (Kassa, 2013). Climate change also affects livestock production as it causes shortage of pastures (animal feed) and water. Crop and livestock pests and diseases are becoming more prevalent; they are spreading to areas that were once too cold for them to live in. For instance, cereal stemborers are expanding their niche to the higher elevation areas (Getu, 2010). Climate change will increase the incidence and severity of plant pathogens and diseases such as coffee leaf rust, cereal rust, smut, *Phytophthora cinnamon*, *P. infestans*, *Plasmopara viticola*, *Botrytis gladiolorum*, chestnut blight disease, citrus canker, root knot nematode, bacterial leaf blight of rice, Stewart's wilt, barley yellow dwarf, potato leaf roll virus, *Citrus tristeza* virus, African cassava mosaic virus and bunchy top of banana, causing severe loss of crop yields (Alemu, 2010). Furthermore, drying up of rivers and lakes as a result of climate change causes shortage of water for irrigation, among others. In Northeastern Ethiopia, drought-induced losses in crop and livestock from 1998–2000 were estimated at USD266 per household – greater than the annual average cash income for more than 75% of households in the study region (Carter et al., 2004).

As a result, agricultural production will greatly decline. Recurrent droughts have had profound impacts on the livelihoods of agriculture- and biodiversity-dependent households, causing millions to rely on food aids. Climate change will increase livelihood insecurity and vulnerability of the people that may ultimately condemn a large part of the population on food aids (Troeger, 2010). Hence, climate variability and change severely affect agricultural production and productivity and thereby the livelihoods of local people and the GDP (Gebrehiwot and van der Veen, 2013; Addisuet al., 2015; FAO, 2016; Teshome, 2016). It is apparent that climate variability and change cause food insecurity and poverty in Ethiopia. Therefore, there is a need for development of drought-resistant crop varieties and climate-smart agricultural practices, technological progress in agriculture including irrigation, and strengthening early warning systems. Increasing agricultural production and productivity in the face of land degradation and climate change is a major challenge for Ethiopia.

Impacts on water availability and supply

Like agriculture, the water sector is the most sensitive to the impacts of climate variability and change. Climate change will alter the hydrology of water resources (streams, rivers, lakes, etc.), thereby affecting the spatial and temporal availability as well as the productivity of water resources (Hailemariam, 1999; IPCC, 2001; USCCSP, 2002; IHP/HWRP, 2008; Ludi, 2009; USGS, 2009; Negash, 2010). It will affect the distribution, quantity and quality of water. As such, climate change will cause shortage of water for domestic, industrial and agricultural/irrigation purposes; fishery and aquaculture; hydroelectric power generation; transportation; water-based recreation; and ecosystem health. It is obvious that water scarcity will be a critical problem in many parts of the country, particularly arid and semi-arid regions. A number of countries in Sub-Saharan Africa (SSA) including Ethiopia have already experienced considerable water stress as a result of climate change (IPCC, 2001); though in areas with predicted increase in precipitation, the situation may be reversed. Furthermore, higher water temperature and reduction in water level will exacerbate water pollution. This calls for not only proper management of both surface and ground water resources but also development of water harvesting technologies. Digging water wells and rainwater harvesting using jars/tanks, ponds and earthen dams are common in Ethiopia. Traditional and modern water harvesting techniques are required for climate change adaptation. Rainwater harvesting and management is a key strategy for climate change adaptation, especially in rural communities in arid and semi-arid areas of SSA including Ethiopia (De Trincheria et al., 2016).

In Ethiopia, almost all of the electricity is generated from hydropower. Thus, the country's energy sector is highly vulnerable to the impacts of climate change. Climate change is expected to alter the hydrology of the Ethiopian rivers, mainly creating increased variability in water level. This has implications to hydroelectric power

generation as both droughts and floods can become more frequent and intense. Droughts can lead to water level decline in dams, while dangerous floods can become considerable safety concerns for dams. More intense rainfall projected to occur as a result of climate change can aggravate soil erosion from uplands and supply sediments into the dams, thereby causing sedimentation. Siltation of Koka Dam has adversely affected the supply of energy in the country (Elias, 2003; Tadesse, 2009). As long as the current practices of deforestation and inappropriate land use continue, any newly built hydropower dams will suffer a similar fate (Tadesse, 2009). Furthermore, heavy rainstorms can destroy energy infrastructure (for example, power transmission and distribution lines).

Impacts on human health

Climate variability and change will have great impacts on human health. Climate change will increase the frequency and severity of pests and diseases. It will increase the prevalence of various tropical diseases (malaria, cholera, yellow fever, meningitis, etc.), which are sensitive to changes in temperature, rainfall and humidity (Adem and Bewket, 2011). Climate change will alter the ecology of some disease-vectors, and consequently the spatial and temporal patterns of transmission of vector-borne diseases. For example, the mosquito belt has considerably expanded to higher elevations due to the temperature incline, and hence malaria is expanding to highland areas which were formerly malaria-free. Evidences indicate that the upper altitudinal limit for malaria transmission in Ethiopia was 2,000 meters above sea level, but in recent years malaria epidemics have occurred in areas with altitudinal limits from 1,600–2,150 meters above sea level (Woyessa et al., 2008). Climate change will lead to increased food and nutrition insecurity, and as such aggravates hunger and malnu-trition, which are prevalent in Africa including Ethiopia. Respiratory ailments like asthma and bronchitis will increase as a result of climate change. Furthermore, heat waves will increase heat-related injuries and deaths. Climate change is expected to compound Ethiopia's health challenges/problems.

Impacts on gender

Gender inequalities influence the specific ways in which climate change affects men and women. As such, women manifest differential vulnerability to the impacts of climate change. Women are the most vulnerable to the climate change impacts due to their socially constructed roles, rights and responsibilities, and they are often poor (Adem and Guta, 2011; Adem and Bewket, 2011; Addisu et al., 2016). Rural women have the major responsibility for household water supply, food security and energy for cooking and heating, and are highly affected by environmental degradation and climate variability and change. Furthermore, women's limited access to resources and decision-making processes increases their vulnerability to climate change (Adem and Bewket, 2011). In many cases, women are insufficiently represented in planning and decision-making processes on community-based climate change mitigation and adaptation strategies. This calls for redressing gender imbalances and empowering women to climate change mitigation and adaptation, among other things.

ETHIOPIA'S RESPONSES TO CLIMATE CHANGE

Ethiopia has shown both conservation and policy responses to combat climate change. Ethiopia is signatory to relevant international environmental conventions and protocols, such as the United Nations Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC), UNCCD, Kyoto Protocol to the UNFCCC and the Paris Agreement. In addition, Ethiopia has been an active participant in international climate negotiations, and initiated and implemented a number of climate-related national strategies and programs.

Ethiopia is taking the necessary steps to implement the two categories of responses to climate change – mitigation and adaptation. Accordingly, Ethiopia prepared its National Adaptation Programme of Action (NAPA) and Nationally Appropriate Mitigation Action (NAMA) and submitted to the UNFCCC in 2007 and 2010, respectively.

To boost socio-economic development and combat climate change, Ethiopia developed a CRGE strategy in 2011 (Anonymous, 2011). The CRGE strategy is based on four pillars:

i) Improving crop and livestock production practices for higher food security and farmer income while reducing GHG emissions;
ii) Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks;
iii) Expanding electricity generation from renewable sources of energy for domestic and regional markets;
iv) Leapfrogging to modern and energy-efficient technologies in transport, industry and buildings.

By implementing the CRGE strategy, Ethiopia aims to achieve a fast economic growth and to be a middle-income country by 2025 and build a climate-resilient green economy with net-zero national GHG emissions by 2030. The net sum of emissions of GHGs in Ethiopia will

be zero because of the removal of GHGs from the atmosphere by the intended increasing vegetation cover. As such, the country aims to achieve economic development with net-zero GHG emissions and resilience to climate change. Ethiopia's CRGE strategy is a good example of an emerging vision in Africa on meeting multiple development goals while contributing to the global effort to mitigate climate change (ODI and CDKN, 2014). In fact, implementation of the CRGE strategy requires commitment at local, national and international levels.

Moreover, Ethiopia established the National Secretariat of Reducing Emissions from Deforestation and Forest Degradation (REDD+) in 2013 under the Ministry of Environment, Forest and Climate Change (MoEFCC). In line with this, Ethiopia prepared its Forest Reference Level (FRL) and submitted to the UNFCCC in 2016, which is intended for accessing the results-based payments under the global REDD+ mechanism, which is part of the Payment for Ecosystem Services (PESs). The design of the national REDD+ strategy is now being finalized. Ethiopia's REDD+ program is aimed at addressing deforestation in priority forest areas in the southern and southwestern and restoration along natural forest areas in the Central, Eastern and Northern Ethiopia.

Nowadays, different mitigation and adaptation strategies are being developed and implemented to intervene to the impacts of climate change and various governmental and non-governmental institutions are being involved in this line. Ethiopia is promoting the conservation, management and sustainable utilization of forests and other natural resources. There are several large projects for afforestation, reforestation, and forest management such as Participatory Forest Management (PFM).

It is assumed that 2 million hectares of pasturelands will be afforested and 1 million hectares of degraded forests will be reforested up to 2030 (Anonymous, 2011). There is a need to enhance the conservation, development and management of forests since they play a vital role in climate change mitigation and adaptation, among others.

Climate change mitigation

Climate change mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2007; Chidumayo et al., 2011). The first option is to reduce the consumption of fossil fuels, thereby reducing GHG emissions; the second one is to maintain and/or increase the vegetation cover, thereby enhancing carbon sinks (carbon sequestration). Thus, climate change mitigation measures reduce the concentrations of GHGs in the atmosphere.

Protected area systems

In order to conserve biodiversity and combat climate change, Ethiopia has given due attention for establishment and management of protected areas. Currently, there are 58 National Forest Priority Areas (NFPAs), 53 wildlife conservation areas (20 national parks, 4 wildlife sanctuaries, 8 wildlife reserves, 18 controlled hunting areas, 3 community conservation areas) and 4 biosphere reserves. Protected areas play a key role in maintaining biodiversity and ecosystem services (soil erosion control, regulation of the hydrological cycle, drought and flood mitigation, carbon sequestration, watershed protection, pest and disease control, etc.). They have environmental, social, economic, cultural, scientific and educational values. Therefore, proper management of the existing protected areas and establishment of new ones in different agroecological zones of the country is crucial for biodiversity conservation, socio-economic development, and climate change mitigation and adaptation. On the other hand, considerable efforts will be required to expand and redesign protected area systems to ensure that they include sufficient area to accommodate management practices that both facilitate change and maintain large populations of species of concern. Ensuring the continued survival of species and ecosystems under changing climatic conditions requires not only adjustments to the extent and location of protected areas but also changes in the ways of managing them (Christian and Grace, 2013). They also pointed out that community-based protected areas, where people live and conduct their livelihood activities (agriculture, hunting, harvesting of forest products, small businesses, etc.) unlike other types of protected areas, are well placed to simultaneously achieve conservation, development and climate change mitigation and adaptation, but the threats posed to biodiversity by the anthropogenic activities taking place within these protected areas should be reduced.

Afforestation, reforestation and forest management: CDM and REDD+

Ethiopia is now taking advantage of the emerging global carbon financing/trading opportunities such as Clean Development Mechanism (CDM) and REDD+ to catalyze afforestation, reforestation and forest management. The CDM and REDD+ projects offer the opportunity to protect the remaining natural forests and restore the forests that have been deforested or degraded due to agricultural expansion and unsustainable utilization. Afforestation and reforestation enhance forest carbon stocks and are thus crucial in climate change mitigation. The CDM afforestation/reforestation (A/R) project at 2,728 ha in the

Humbo District (Wolayita) in Southern Ethiopia is expected to cut about 880,296 tons of CO_2 from the atmosphere in 30 years (Anonymous, 2006). The REDD+ project at 600,000 ha in the Bale Mountains is expected to generate about 80 million tons of CO_2 emission reductions worth of USD320 million, and the CDM reforestation project at 3,000 ha about USD5.2 million, both in 20 years (Tadesse, 2009). Such projects will bring environmental, social and economic benefits to the local communities and beyond.

There is a need to develop biodiverse carbon-rich plantation forests rather than fast growing single species plantations (that is, monocultures) to achieve both biodiversity conservation and climate change mitigation (Pichancourt et al., 2013). This requires planting diverse tree species with multiple environmental and socio-economic benefits, especially high carbon stocks. It also requires that the species are spatially distributed across landscapes.

Finding evidence and technical solutions for building larger and more stable stocks of carbon in biodiverse forests has attracted much attention in recent years from global initiatives such as REDD+. To improve the resistance/stability and resilience/recovery of forests to climate change, there is a need to increase the number of tree species and structural diversity of plantation forests and apply close-to-nature silviculture (Berendt et al., 2017). Hence, tree planting in Ethiopia needs to be fine twined in line with the aforementioned approaches. The forestry sector plays a critical role to mitigate and adapt to the impacts of climate change, and thus forest resources management and development should be a priority.

Development of renewable energy sources and energy efficiency

Ethiopia is now aggressively promoting the development of renewable energy sources and energy efficiency to reduce deforestation and environmental degradation, enhance socio-economic development and fight climate change. Development of renewable sources of energy (hydroelectric, wind, solar, geothermal, biomass, biogas, biofuel) and energy efficiency (for example, fuelwood-efficient/energy-saving stoves, higher efficiency light bulbs) and import and/or assembly of fuel-efficient and electric vehicles, are all important measures taken to this end. All these measures will help to:

i) Reduce the dependency on biomass as a source of energy, thereby reducing deforestation;
ii) Supply the energy that the growing economy demands;
iii) Reduce GHG emissions;
iv) Reduce the import of fossil fuels (that is, saving foreign currency).

Development of renewable energy sources is a viable option for Ethiopia for meeting both environmental and development goals.

Climate change adaptation

Adaptation to climate change refers to adjustments in environmental, social and economic systems in response to the actual and expected impacts of climate change. Adaptation moderates vulnerability to climate change. An effective climate change adaptation policy must be responsive to a wide variety of environmental, social, economic, cultural and political circumstances. Adaptation to climate change has to be localized, given that adaptation to climate change is inevitably and unavoidably local (Blaikie et al., 1994; Ribot, 1995). As such, adaptation has to be a national priority and requires committed local action (Bewket, 2011). Adaptation strategies need to be diverse and specific to a particular location based on traditional roots and should benefit from modern science (Asfaw, 2010). Adaptation to climate change requires combining scientific knowledge with indigenous knowledge and practices. Moreover, adaptation to climate change needs to be a continuous endeavour.

In Ethiopia, communities have important indigenous knowledge, skills and technologies that are essential for tackling hazardous environmental conditions including climate variability and change. In fact, they employ a number of short- and long-term climate change mitigation and adaptation strategies to cope with and overcome the impacts of climate variability and change (Table 1).

Thus, the use of indigenous knowledge and local coping strategies should be promoted as a starting point for planning climate change mitigation and adaptation (Chidumayo et al., 2011; Zegeye, 2013). However, the ability of communities to adapt to the impacts of climate variability and change is constrained by a number of factors/barriers (Table 2).

Thus, the constraints to climate change adaptation are biophysical, human, financial, technical, technological, institutional, infrastructural, informational and political. Therefore, communities need to be assisted to build their resilience against current and future climate stresses using indigenous knowledge and local coping/adaptation strategies and adopting appropriate technologies that are harmonized with government plans and research directions (Asfaw, 2010). Reducing exposure and sensitivity along with increasing adaptive capacity and strengthening the adaptation processes through building on existing adaptation practices are suggested (Alemayehu and Bewket, 2016). Because of their limited adaptive capacity and the pressing impacts of climate change, communities now require tailored support (human, financial, technical, technological, institutional,

Table 1. The most notable traditional climate change mitigation and adaptation strategies in Ethiopia.

Traditional climate change mitigation and adaptation strategies
• Soil and water conservation (terracing, crop rotation, intercropping, mulching, crop residue retention, use of animal dung, composting, use of synthetic fertilizers, etc.)
• Tree planting (homegardening, traditional agroforestry)
• Crop diversification (growing different crops and varieties)
• Livestock diversification and use of cross-breeds
• Small-scale irrigation (by households and community groups)
• Changing crop sowing dates
• Grain storage and reduction of postharvest loss
• Collection of wild foods (edible fruits and vegetables, fish)
• Traditional water harvesting and storage (use of water wells, rainwater harvesting)
• Rangeland management
• Management of wildfires
• Indigenous forecasting and early warning systems
• Growing fruit plants (e.g. apple in the highlands)
• Sale of grains and livestock and their by-products
• Livelihood diversification and adjustment (off-farm income, seasonal migration, change in consumption pattern, taking credit, borrowing grain and/or money from relatives, land renting and remittance, seeking food aids during periods of droughts and crop failures)
• Mobility, that is, livestock and/or people (pastoral and agropastoral communities)
• Involvement of traditional institutions (Edir, Equb, religious institutions) and social networks
• Looking for assistance from the government and international agencies (e.g. food aid)

Sources: Bryan et al. (2009), Deressa et al. (2009, 2011), Riché et al. (2010), Asfaw (2010), World Bank (2011), Zegeye (2013), Kassa (2013), Tadesse et al. (2013), Addisu et al. (2016), Alemayehu and Bewket (2016), Simane et al. (2016), Zerga and Gebeyehu (2016), Belay et al. (2017), Mekonnen et al. (2017) and Tilahun et al. (2017)..

Table 2. Factors/barriers limiting the ability of communities to adapt to the impacts of climate variability and change.

Limiting factors
• Human population growth (large family size)
• Inappropriate land use and forest policies, strategies and programs
• Low institutional capacity of local bodies
• Marginalization of local communities in decision-making concerning their natural resources conservation and utilization
• Deforestation, overgrazing, soil erosion and decline in soil fertility
• Limited access to land (the average landholding size per household is generally less than 1 ha)
• Poor access to planting materials (improved crop seeds, tree seeds and seedlings)
• Lack of data and information on climate change and its impacts
• Outbreak of (crop, livestock, human) pests and diseases
• Limited access to extension services
• Limited water supply
• Limited access to health services
• Limited access to education and training
• Limited infrastructure (schools, roads, electricity, telephone, potable water reservoirs, irrigation dams)
• Limited access to new skills and technologies
• Conflicts over scarce resources (grazing lands, water points)
• Poor access to markets and financial resources and services (funding, credits)
• Inappropriate development interventions (e.g. villagization/resettlement)
• Disruption of traditional social networks and transformation to new social relationships

Table 2. Contd.

• Poverty (low income) • Insecure land tenure • Gender inequalities

Sources: Bryan et al. (2009), Deressa et al. (2009, 2011), Riché et al. (2010), Troeger (2010), Zegeye (2013), ODI and CDKN (2014), Addisu et al. (2016), Alemayehu and Bewket (2016), Simane et al. (2016), Zerga and Gebeyehu (2016), Tilahun et al. (2016, 2017) and Belay et al. (2017).

and infrastructural) from the government and other relevant stakeholders (scientists, development partners, NGOs, international donors, etc.). On the other hand, there are a number of development partners and NGOs that are providing support to increase adaptive capacity to the impacts of climate change, for instance, Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), World Food Programme (WFP), CARE International, World Vision and World Bank.

Ecological agriculture

Ecological agriculture, also known as conservation agriculture and climate-smart agriculture, has a high potential for both climate change mitigation and adaptation in Africa (Ching et al., 2011). As such, ecological agriculture is a viable option for Ethiopia. Ecological agricultural practices include terracing, crop rotation, intercropping, retention of crop residues and use of animal dung, composting, mulching, crop diversification (including farmers' varieties), water harvesting and storage, homegardening and traditional agroforestry, management of grazing areas, etc. Ecological agriculture such as avoiding the use of inorganic fertilizers results in reduced GHG emissions, particularly nitrous oxide. The agricultural system of the Konso people in southern Ethiopia is famous for its perfect adaptation to a harsh environment of steep, stony hills and little rainfalls. Traditional technologies are used for soil and water conservation, water harvesting and many more. The Konso agriculture is one of the first examples given to show that adaptation to climate change will be no problem for Ethiopia as suitable and sustainable mechanisms already exist (Kebede et al., 2010). In the face of environmental degradation, climate change and poverty, enhancing ecological agriculture is of paramount importance. The Tigray Project on ecological agriculture has showed positive results, both in terms of rehabilitation of degraded lands and improvement of livelihoods of local communities, and is being scaled up to many areas within the region and other regions of the country (Ching et al., 2011). The adoption of climate-smart agriculture would enhance productivity and the income of farmers, while contributing to the amelioration of the negative effects of climate change (FAO, 2016).

Flexible livestock production

Pastoralism and agropastoralism are common practices in Ethiopia. Like agriculture, they are climate-sensitive sectors. On the other hand, pastoralists and agro-pastoralists in the drylands such as Afar in northeastern, Somali in eastern and Borana in Southern Ethiopia use different strategies to cope with the impacts of climate variability and change (Table 3). Nowadays, the pastoralists in the drylands such as Afar, Somali and Borana are decreasing the number of cattle and sheep and increasing the number of camels and goats (because of their remarkable capacity to adapt severe drought) in their herds as a strategy to improve their livelihoods and adapt to climate change (Aklilu and Catley, 2010; Tadesse et al., 2013). The Borana people have elaborate institutions for ensuring that their livestock are able to maintain access and good care for pastures and water points. Pastoral communities in Afar, Somali and Borana are in tune with climate change and are able to adapt to the vagaries of climate change with their own short- and long-term strategies (Riché et al., 2010; Tilahun et al., 2017).

Homegardens and traditional agroforestry systems

Homegardening and traditional agroforestry are age-old practices in Ethiopia. Homegardening is the growing of a variety of plants (trees, shrubs, vines, herbs) around homes to produce diverse goods and services. Agroforestry is the integration of trees and shrubs with crop and livestock production systems, that is, a combination of agriculture and forestry. Homegardens and traditional agroforestry systems are time-honoured, interrelated production and agrobiodiversity management systems widely practiced in the Ethiopian agricultural landscapes. A wide range of homegardens and agroforestry systems exist in different parts of the country. The traditional agroforestry systems in Konso, Sidama, Gedeo and the Rift Valley are worth-mentioning.

Table 3. Strategies used by pastoralists and agropastoralists in the drylands of Ethiopia to cope with the impacts of climate variability and change.

Strategies for coping with the impacts of climate variability and change
• Mobility (livestock and/or people)
• Modifying livestock composition (rearing different livestock species) and herd size (herd splitting; decreasing the number of livestock through selling and slaughtering/feeding during periods of droughts in which there is scarcity of water and forage, and increasing through purchasing during inter-drought periods)
• Construction and maintenance of water storage infrastructure
• Use of crop residues as animal feed
• Hay making, collection and preservation
• Reserving dry season grazing areas
• Modification of rangeland management practices (controlled grazing/regulating the frequency and intensity of grazing, controlled burning for acquisition of new growth for livestock grazing)
• Effective, efficient and participatory management of available natural resources
• Tree planting (for livestock feed and shade)
• Modification of farming practices
• Diversifying livelihood activities
• Increasing education for children
• Establishing community groups to overcome the impacts of droughts and provide alternative means of support
• Raising community awareness on climate change issues and needs for adaptation
• Strengthening existing conflict resolution mechanisms and rethinking regional boundaries

Sources: Riché et al. (2010), Chidumayo et al. (2011), Tadesse et al. (2013) and Tilahun et al. (2017).

The major types of agroforestry systems in Ethiopia are homestead tree planting (homegarden agroforestry), farmland tree planting, farm boundary tree planting, farm woodlots and roadside tree planting. Windbreaks/ shelterbelts are also emerging agroforesty systems. Homegardens and agroforestry systems have a range of environmental, social, economic and cultural benefits. They help to sustain the environment and improve livelihoods of people, and as such hold considerable potential for human and livestock adaptation to climate change (FAO, 2000; Asfaw, 2010; Zegeye, 2013). They control soil erosion, improve soil fertility, sequester carbon, moderate microclimate, provide various products (fuelwood, charcoal, construction material, timber, poles, posts, farm implements, food, medicines, fodder, spices, bee forage, etc.), increase income, and provide shade and amenity. They supplement food supplies and also serve as a buffer during periods of droughts and crop failures. Moreover, they are well placed for adding new plants to the existing flora (domestication of wild plants).

Thus, homegardens and agroforestry systems can play a key role in climate change mitigation and adaptation in Ethiopia. In the face of climate change, combining the two in farming systems would be advantageous since their synergy optimizes mitigation and adaptation (Asfaw, 2010).

Harvesting and use/marketing of non-timber forest products (NTFPs)

Non-timber forest products (NTFPs) are products other than timber, as well as services, derived from forests. The NTFPs are harvested from forest areas and are produced in farmers' fields (homegardens, agroforestry systems). The major NTFPs include food, medicines, fodder, coffee, honey and beewax, bamboo, fibres, spices, oils, gums, resins, tannins, dyes, latexes, etc. Local people are engaged in harvesting of NTFPs for use and/or marketing (income generation) as a coping strategy to adverse climatic conditions, particularly during periods of droughts and crop failures. Wild and semi-wild plants like *Cordia africana*, *C. monoica*, *Balanites aegyptiaca*, *Dovyalis abyssinica*, *Ficus sur*, *F. vasta*, *F. sycomorus*, *F. ingens, Rosa abyssinica*, *Carissa spinarum*, *Rhus natalensis*, *R. vulgaris*, *Grewia ferruginea, G. bicolor*, *G. velutina*, *Rubus steudneri*, *Syzygium guineense*, *Mimusops kummel*, *Opuntia ficus-indica*, *Ximenia americana*, *Acokanthera schimperi, Tamarindus indica*, *Ziziphus spina-christi*, *Oncoba spinosa* and *Phoenix reclinata* provide edible fruits. *Moringa stenopetala* and *M. oleifera* provide edible leaves and shoots, which are nutrient- and vitamin rich. Local people are also engaged in harvesting of wood

products (fuelwood, charcoal, construction material, timber, farm implements, carvings) from nearby woody vegetation for consumption and/or income generation through sale, but this is not a sound strategy as it causes deforestation – one of the major drivers of climate change (Zegeye, 2017).

Climate change education (CCE)

In Ethiopia, there is generally low awareness on climate change. Thus, it is crucial to raise awareness about climate change and its impacts in the policymakers and the general public. This can be done using a variety of methods: print media (newspapers, leaflets, books, journal articles); meetings (conferences, workshops, seminars, symposiums, panel discussions); electronic media (radio, TV, internet); and bulk short text messages [bulk short message service (SMS) using mobile]. Furthermore, key environmental issues are not properly integrated into the curricula, though some elements are incorporated. Thus, there is a need to inculcate the whole range of environmental issues, especially environmental protection, biodiversity conservation and climate change, in the curricula of schools and higher learning institutions so as to raise the environmental awareness of the young generation. Biology, agriculture, forestry, geography, environmental sciences and natural resources management are important fields that can make significant contributions to environmental education in Ethiopia. Deeb et al. (2011) pointed out that climate change education is greater than climate science and requires teaching across all people of all ages and engages with formal (that is, schooling), non-formal (for example, training for the workforce) and informal (for example, media) education. To this end, various governmental and non-governmental organizations and professional societies (for example, the Biological Society of Ethiopia) are advocating about climate change and its impacts in Ethiopia. Moreover, Ethiopia currently developed climate change education strategy for the period 2017–2030, which mainly focuses on strengthening the integration of climate change education (CCE) into the formal education system of the country (MoEFCC and MoE, 2017). The strategy indicated that CCE is a vital necessity to the success of Ethiopia's drive to build a green and resilient economy by 2030 and beyond.

OPPORTUNITIES ARISING FROM CLIMATE CHANGE

Climate change presents both risks/challenges and opportunities in the world including Ethiopia. In Ethiopia, climate change has provided opportunities to focus on issues of relevance to environmental wellbeing and livelihood improvement. It has made it necessary to give more emphasis on land use planning, conservation and sustainable use of natural resources and development of renewable energy sources in an urgent manner. Efforts are being made to protect the existing forests and promote tree planting (afforestation, reforestation, agroforestry). The emerging global carbon financing can bring opportunities for catalyzing biodiversity conservation and socio-economic development in Ethiopia and elsewhere.

There are several climate financing mechanisms at international level designed to enhance mitigation of and adaptation to climate change. These include the CDM, Adaptation Fund, Climate Investment Fund (CIF) of the World Bank, Green Climate Fund (GCF) of the United Nations (REDD+ is part of this fund), Nordic Climate Facility (NCF) of the Nordic Development Fund (NDF), and Urban and Municipal Development Fund for Africa of the African Development Bank (AfDB). Thus, Ethiopia should strive to seize the global climate financing opportunities to promote the conservation and sustainable use of biodiversity and socio-economic development including climate-resilient urban development. With appropriate planning and implementation, the threats/challenges posed to biodiversity and humanity by climate change can be transformed into opportunities that can enhance biodiversity conservation and socio-economic development.

CONCLUSION AND RECOMMENDATIONS

Both climate variability and change have been occurring in Ethiopia. Evidences show that since 1960 the mean annual temperature of the country has risen by about 1.3°C, an average rate of 0.28°C per decade, and spatial and temporal rainfall variability has been increasing. As such, Ethiopia has been experiencing the impacts of both climate variability and change. Climate change has led to recurrent droughts and famines, flooding, expansion of desertification, loss of wetlands, loss of biodiversity, decline in agricultural production and productivity, shortage of water, and increased incidence of pests and diseases such as spread of cereal stemborers and malaria to higher elevation areas. Climate change is likely to aggravate environmental degradation, food insecurity, water scarcity, disease epidemics and poverty in Ethiopia. It is apparent that climate change will have dramatic environmental, social, economic, cultural and political impacts. Ethiopia is vulnerable to the impacts of climate change mainly due to geographical location, rapid human population growth, heavy dependence on agriculture and natural resources for subsistence, widespread poverty and limited resources (human, financial, technical, technological, institutional, and infrastructural). It also has in general low adaptive capacity to the impacts of climate change.

On the other hand, Ethiopia has shown both conservation and policy responses to combat climate change. Protected area systems, afforestation and reforestation programmes, development of renewable energy sources and energy efficiency, ecological agriculture, flexible livestock production, homegardens and traditional agroforestry systems, harvesting and use/marketing of non-timber forest products and climate change education, are all feasible strategies for mitigating and adapting climate change. Indeed, there is a need to employ the right mix of climate change mitigation and adaptation strategies prioritized in space and time so as to reduce vulnerability of biodiversity and humanity to the escalating impacts of climate change. To this end, capacity building should be a priority. Moreover, there is a need to collaborate with the international community to combat climate change, which is a global challenge.

Therefore, in order to combat climate change and thereby ensure environmental stability and improve human wellbeing in Ethiopia and elsewhere, the following recommendations are forwarded:

- Develop appropriate land use and forest policies, strategies and programs;
- Raise awareness about climate change and its impacts in the policymakers and the general public;
- Ensure the involvement of local communities and all other relevant stakeholders in climate change mitigation and adaptation planning and implementation;
- Mainstream climate change mitigation and adaptation into environmental and development policies, strategies and programs;
- Shift from fossil fuels to renewable energy sources and energy efficiency (reduce the anthropogenic emissions of GHGs);
- Promote integrated and sustainable natural resources management (air, water, soil, forests, and wildlife);
- Promote tree planting (afforestation, reforestation, and agroforestry) with emphasis on multipurpose and highly adaptable tree and shrub species (primarily indigenous species, suitable exotic species can be used as deemed necessary);
- Ensure proper management of water resources;
- Improve agricultural production and productivity using appropriate agricultural technologies and inputs (employ climate-smart agriculture);
- Enhance agricultural and forestry extension services;
- Build climate change mitigation and adaptation capacity (human, financial, technical, technological, institutional, and infrastructural);
- Promote climate change research, education and training;
- Scale up the indigenous climate change mitigation and adaptation strategies and develop or adopt new technologies;
- Integrate indigenous and scientific knowledge in climate change mitigation and adaptation strategies and practices;
- Enhance the green economy;
- Promote the exchange and dissemination of data and information on climate change and its impacts;
- Empower communities, particularly the disadvantaged (poor, marginalized) and most vulnerable social groups such as women and pastoralists, to climate change mitigation and adaptation;
- Provide safe and adequate water, modern health services, financial services, transport and attractive market system for local communities;
- Promote local, national, regional and international collaborations and networking on environmental, development and climate change issues;
- Allocate domestic budget to climate change mitigation and adaptation interventions;
- Seek international support for climate change mitigation and adaptation.

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