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Ethiopia - Land, climate, energy, agriculture and development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

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Ethiopia – Land, energy, climate change, and agricultural development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

Assefa Admassie and Degnet Abebaw

Abstract

Ethiopia is the second most populous country in Sub-Saharan Africa with a population of more than 110 million. With over 10 percent growth rate, the Ethiopian economy has been one of the fastest growing economies in the world over the last one and half decades. By any measure agriculture is the dominant economic sector in the country accounting for a sizeable portion of the GDP growth, generating most of the export earnings and employing most of the labour force. The country has diverse agro-ecological conditions which are suitable for growing both temperate and tropical food and industrial crops. This study has tried to review the trends in environment conditions such as energy use, land cover and land use changes as well as the impact of climate change and the policy responses of the Government of Ethiopia. The review clearly shows that Ethiopia is still a poor country with more than one fifth of the population living below the national poverty line. Food insecurity continues to be a big challenge for millions of Ethiopians. Despite being the dominant economic sector, agricultural production is characterized as a low-input-low productivity sector. Land degradation is a very serious problem in Ethiopia due to the fact that many parts of the Ethiopian highlands are mountainous and rugged. Even though Ethiopia has huge potential for generating renewable energy, the majority of the Ethiopian population still relies on biomass energy sources such as wood, animal dung and crop residues. These environmental challenges are also exacerbated due to the effect of climate change. To mitigate the impact of land degradation, deforestation, and climate change, the Government of Ethiopia has formulated and implemented several policies. The Agricultural Growth Program (AGP), the Productive Safety Net Program (PSNP), the Sustainable Land Management Program (SLM) and the Climate Resilient Green Economy (CRGE) strategy are the major programs being implemented to address these environmental challenges. Indeed, these interventions have made noticeable contributions to curb the challenges.

Keywords: Ethiopia, food insecurity, biomass energy, agricultural development, land degradation, climate change, policy responses

JEL codes: Q18, Q15, Q24, Q42, Q54, Q58

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1 Introduction

With a population of more than 107 million people in 2017 (World Bank, 2018), Ethiopia is the second most populous country in Sub-Saharan Africa. Although the rate of urbanization has recently been increasing, most of the Ethiopian population still lives in rural areas where poverty and hunger are rampant. The rate of population growth is estimated to be around 2.5 per annum, which could compromise the social and economic gains the country has recently achieved. In addition, the fast rate of population growth will also lead to high farmland degradation and fragmentation resulting in a reduced amount of farmland. It also exerts serious pressure on demands for social services and strains the labour market, which is already failing to provide adequate employment opportunities. Another important feature of the Ethiopian population is that more than 60 percent are under the age of 25 years and 70 percent are under 30 (Admassie *et al.,* 2015).

The population growth has also been accompanied by a growing labour force, with the growth being more pronounced in urban areas than in rural areas. Employment creation is among the primary policy goals of Ethiopia, as asserted in various policy documents including the latest GTP. Policies and strategies on the demand side of the labour markets include special incentives and means of supports provided to investors in the private sector, with a special focus on labour-intensive programmes, and public employment generation schemes, such as the Productive Safety Net Programme (PSNP). On the supply side of the labour market, there are efforts to improve labour productivity in both farm and off-farm activities. Despite these efforts, many people in Ethiopia either do not have jobs or are engaged in low-productivity activities due to a host of structural problems on both the demand and supply side. The demand-side factors are mainly associated with the lack of absorptive capacity of the economy or the economy's lack of ability to create new jobs; on the supply-side, low education levels, along with a lack of training and experience limit employment opportunities.

Consequently, unemployment is a growing and serious problem in Ethiopia, particularly for the youth. Moreover, many people work either less than full-time (open underemployment) or work full-time but at low intensity (disguised underemployment) (Martha, 2012). The labour market in Ethiopia is also segmented, with important distinctions occurring between formal and informal employment, private and public job markets, wage employment and self-employment, and between urban and rural labour market opportunities. The dominant employment in rural areas for the working age population, including the youth, remains smallholder agriculture (World Bank, 2016). According to the National Planning Commission (2017), the share of the total labour force employed in agriculture will decline from 75 percent in 2014/15 to 67.5 percent in 2019/20.

The total land area of Ethiopia is estimated to be around 112 million hectares, out of which more than 65 percent is believed to be suitable for some form of agricultural production. Ethiopia also has one of the largest and most diverse genetic resources in the world. In terms of agro-ecology, the country has great geographic, climatic, soil and vegetation diversity, making Ethiopia a suitable place for the production of different types of food and industrial crops.

During the last decade and a half, Ethiopia has become one of the fastest growing economies in the world. Since 2005 Ethiopia's economic performance has been remarkably strong. More recently, real GDP growth averaged 10.9 percent in 2016/17 according to official figures, out of which the agriculture sector accounted for 2.5 percent, while the industry and service sectors accounted for the remaining balance (EEA, 2018). However, due to a slowdown in industrial growth, mainly driven by lower growth in construction, real GDP growth declined to about 7.7 percent in 2017/18 (World Bank, 2018). As a result of the fast GDP growth, GDP per capita has also increased progressively over the years, registering an annual average growth rate of 8 percent (World Bank, 2016). The main source of the economic growth is the public sector-led development strategy focusing on heavy investment in infrastructure. As a result, Ethiopia is now East Africa's largest economy (IMF, 2018).

Although its contribution has started to decline, agriculture still accounts for about 37 percent of the GDP and provide employment to most of the rural population[1] (NBE, 2018). The sector also generates more than 80 percent of export earnings. In terms of budget allocation, Ethiopia has allocated an average 10 percent of the national public budget to agriculture. Except for the modest growth in crop yield, the agricultural sector, however, still remains low in both labour and land productivity and suffers from poor utilization of improved technologies, whether in seeds, fertilizer, pesticides, irrigation, mechanization or post-harvest technology (Bachewe *et al.,* 2016; Diriba, 2018). While agriculture was the main contributor to growth in the past, the service sector has gradually taken over in recent years.

Apart from GDP growth, substantial progress has also been made on many other economic and social indicators over the past two decades. For instance, life expectancy at birth rose to about 66 years in 2018. Poverty also decreased substantially over the same time period. The proportion of people whose income is below the poverty line has declined from around 45.5 percent in 1995/96 to 23.5 percent in 2015/16[2] (NPC, 2017), with more pronounced reduction in poverty in urban areas.[3] Nevertheless, quality of life has not improved significantly despite the expansion in access to education and health services. According to the Human Development Report, Ethiopia's HDI value for 2017 was only 0.463, placing it at 173 out of 189 countries (UNDP, 2018).

In addition to the income poverty measure, Ethiopia is also considered poor based on several non-income poverty measures. For instance, access to safe drinking water is another indicator of the non-income dimension of poverty. Although access to safe water is on the rise, millions of people in rural areas are still not getting regular access to safe water. Access to energy is another indicator of the dimension of non-consumption poverty. Although Ethiopia is endowed with the huge potential of a variety of renewable energy sources, biomass energy coming from wood, animal dung and crop residue remains the major source of domestic energy. This high dependency on biomass sources of energy has led to massive deforestation, loss of soil nutrients and organic matter. Ethiopia is also vulnerable to other environmental challenges, including land degradation, climatic variation, drought and flooding.

Land degradation, which manifests itself in many different ways, such as vegetation becoming increasingly scarce, water courses drying up and soils becoming thin and stony, is one of the most serious environmental problems facing the country's agriculture and food security. The major causes of land degradation are rapid population growth, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production. According to Gebreselassie *et al.* (2017), more than 85 percent of the land in Ethiopia is degraded, the annual cost of which is estimated to be about $4.3 billion.

The main objective of this paper is to review the current state of affairs in Ethiopia with regards to land degradation, climate change and energy, and to identify investment opportunities that will help in advancing economic growth, food security and job creation. To achieve this, the paper has attempted to review existing documents. Accordingly, government documents such as policy documents, administrative reports, project documents, journal articles, books, manuscripts, and similar published and unpublished documents have been systematically reviewed. Both printed and electronic media have been surveyed.

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[1] Because of exponential growth in the construction, whole- and retail-trade as well as hotel and restaurant sub-sectors, the service sector replaced the agriculture sector as the most dominant economic sector. Agriculture's relative share in the GDP fell from over 60 percent in the 1990s to about 37 percent in 2016/17 while the service sector's contribution increased to over 39 percent (EEA, 2018).

[2] This level of poverty is low relative to the international standard. As per the international standard poverty line (USD1.9 per capita per day) the headcount ratio was 34 in 2010/11 and 27 percent in 2015/16.

[3] Nevertheless, those who are declared to have been lifted out of poverty remain close to the poverty line and risk sliding back below the line with the slightest misfortune.

2 Situation and trends in rural energy, and land use changes

2.1 Energy use and associated challenges and opportunities

According to the second Growth and Transformation Plan (GTP II), Ethiopia aspires to transform itself from being a least developed country to a middle-income country by 2025. In order to realize this ambition and, in view of the fact that its population and economy are growing rapidly, access to energy is one of the key necessities. The rapid economic growth that was achieved over the last one and a half decades has demanded a commensurate increase in energy. Access to renewable clean energy is among the key factors for the development of the Ethiopian economy. Accordingly, Ethiopia has put in place several strategies to increase and diversify access to electricity, clean water and clean energy from renewable energy sources. For instance, more than 13.7 GW of new renewable energy is planned to be supplied from sources other than hydroelectricity during the second GTP period. Ethiopia also aspires to export electricity to neighbouring countries (IFPRI, 2018).

Ethiopia has the potential to generate over 60,000 megawatts (MW) of electric power from renewable energy sources, such as solar, water, wind and geothermal (Mondal *et al*., 2017). According to information from Ethiopian Electrical Power (2016), Ethiopia has the capacity to produce more than 45 MW of electricity from hydropower, 4-6 kWH/m2 from solar energy per day, about 100 GW of wind power per second, and more than 10,000 MW from geothermal sources. The reserve of fossil fuels is also significant. For example, natural gas reserves are estimated to be about 4 trillion cubic feet and coal reserves at over 300 million tons. In addition, millions of tons of wood, agricultural waste, coal and oil shales could become important sources of energy in Ethiopia. Thus, there are many alternative energy sources to meet Ethiopia's electricity-access goals. However, despite these huge potentials, access to energy is still inadequate in Ethiopia. The demand for electricity in the country is enormous and is projected to grow by more than 30 percent annually. Weak technical and institutional capacity, lack of finance and policy-related factors are among the main reasons for the underutilization of the energy potentials of the country.

The Ethiopian energy market is broadly categorized into two major groups: the traditional biomass-based fuels consisting of fuelwood, animal dung, crop residues and charcoal; and the modern or commercial energy sources including oil products and electricity. At the moment, the traditional energy sources, represent the principal sources of domestic energy in Ethiopia. The majority of the rural population, which is estimated to be over 80 percent, largely rely on traditional biomass energy sources for cooking and heating.

As mentioned above, the main energy source in Ethiopia is based on biomass and access to modern energy services is extremely limited. Currently, no more than 44 percent of the total population have access to electricity (WB, 2019). There are also significant differences in the rate of electricity access between urban and rural areas—in urban areas, 85 percent of the population has access to electricity, while in rural areas electricity access remains extremely low at less than 30 percent (USAID, 2018).

Looking at the share of different energy sources in Ethiopia, biomass energy, with a share of 92.2 percent of the energy supply, was the country's primary energy source in 2014, followed by oil (5.7 percent) and hydropower (1.6 percent), with the remaining balance accounted for by geothermal, solar and coal energy (International Energy Agency, 2014 cited in Energypedia, 2020). The share of biomass energy decreased from 96.6 percent in 1996 to 92 percent in 2010, while the share of petroleum fuels and electricity increased from 4.8 percent to 6 percent and from 0.6 percent to 2 percent, respectively, over the same period. The projected demand for 2030 shows that biomass demand will decrease to 71.6 percent, while demand for petroleum and electricity will increase to 22.6 percent and 5.8 percent, respectively (FDRE, 2010). Although these figures show that there is a gradual shift towards modern sources of energy such as petroleum and electricity, biomass energy will continue to be the main source of energy for the foreseeable future.

With respect to sectoral energy consumption, approximately 89 percent of the biomass energy is consumed by households, 10 percent by services and one percent by agriculture. Energy consumption by the industrial sectors is very minimal. The Ethiopian agricultural sector relies exclusively on human and animal power. In addition, the cottage industries that exist in rural areas also use very few modern energy services. However, access to petroleum fuels and electricity in urban areas has enabled a significant proportion of the population to employ modern energy services for cooking and other domestic energy requirements. The transport sector primarily depends on petroleum fuels, which accounts for over 80 percent of the consumption of petroleum products, while urban households use kerosene for cooking and lighting. The modern industrial sector uses mostly electricity and oil to meet its energy requirements.

The high dependency on biomass fuels, particularly in the household sector, will be unsustainable and lead to significant environmental challenges. As a result of the exclusive dependency on biomass sources of energy, deforestation will increase, land degradation will be intensified, agricultural productivity will decline, and greenhouse gas emissions will increase. However, if rural households are provided with electricity, even for lighting, the gain in terms of environmental protection will be significant.

As access to modern energy sources on regular basis is extremely limited in rural Ethiopia, most of the rural population has no alternative other than to use biomass energy fuels that are often freely gathered from the local environment. The increasing energy demands in rural areas is met by gathering more fuel wood and clearing more land for agriculture, which exacerbates the problem of deforestation. Rural households also do not have the required finance to pay for modern commercial fuels even if they were available. Wood fuel is generally collected mainly from commonly accessible forest land and from farmland. Consequently, the available stock of traditional biomass energy resources is decreasing quickly due to the rapid population growth and the absence of alternative energy services other than the biomass-based sources. As a result, shortages of fuelwood have become very acute in many parts of Ethiopia. The problem is further aggravated by other socioeconomic and environmental factors, including deforestation[4] (Mulugetta, 2007; Karakezi, 2003; Karakezi and Kithyoma, 2002). Reduced access to woody biomass has had serious developmental and social impacts including deforestation. As the study by Bishaw (2011) demonstrated, the loss of forest cover contributes to soil erosion and a loss of nutrients necessary for agriculture, which further leads to clearing of forests for new farming plots.

Increased deforestation also implies an increase in the distance travelled as well as the time and effort invested to gather fuelwood. Fuelwood energy stress directly impacts women and children, since fuel gathering in rural Ethiopia is almost exclusively the domain of women, and to some extent of children. The increasing collection distance places additional burdens on the labuor budget of women. As the World Bank (2010) report points out, electricity is a crucial element of human development, as it leads to more free time, improved health, and higher education levels. Furthermore, fuel wood scarcity brings increased encroachment into forest areas.

In addition, urban fuelwood demand also has a significant impact on rural areas that supply wood fuels to the urban market and the increasing commodification of wood fuels can lead to competition with local needs for woody biomass. Growing charcoal demand in urban areas also contributed to negative results in Ethiopia. Thus, urban fuelwood demand is an important contributor to deforestation and fuelwood shortage in Ethiopia.

The declining wood resources also lead to an increase in the use of animal dung and crop residues as fuel instead of recycling them as fertilizer, thereby increasing the damage to agricultural productivity.

[4] Shortage of fuel wood is both a consequence and a cause of deforestation. But, while deforestation may be the prime reason for the decrease in fuelwood supplies, fuelwood-cutting may not necessarily be the only cause of deforestation. Other factors, mainly forest removal for agricultural expansion and grazing land in the face of human and livestock population growth, are often equally, if not more influential agents of deforestation in Ethiopia.

This practice will destabilize the balance between what goes in for agricultural production and animal manure for fertilizer, and what goes out of it, i.e. food for humans and animals. According to Woods (1990), diverting dung to energy needs in Ethiopia has contributed to about a 10 to 20 percent fall in crop production.

2.2 Dynamics of land degradation, land use and land cover changes over the last 30 years

To date, agriculture in Ethiopia uses around 40 percent of the country's land (Hailemariam *et al.,* 2016). As stated earlier, land degradation is a crucial problem for agricultural development and the environment in Ethiopia. Among others, land degradation is caused by land use and land cover (LULC) change and climate change (Berihun *et al*., 2019; Hailemariam *et al.,* 2016). A number of past studies (e.g. Berihun *et al.,* 2019; Kassawmar *et al.,* 2018; Hailemariam *et al.,* 2016) show that in Ethiopia LULC change is mainly associated with forest conversion to agricultural land.

Several authors have examined the extent and patterns of land use and land cover (LULC) change in Ethiopia (see Hailu *et al.,* 2018 for a detailed review). For instance, Berihun et al. (2019) studied the dynamics using empirical data for the time period 1982-2017 for three sites in Ethiopia (i.e. Guder, Aba Gerima, & Debatie). According to the authors, in 1982, about 41 percent and 32 percent of the lands in Guder and Aba Gerima, respectively, were covered with forests. At the same time, bushland was the main type of land in Dabatie. Between 1982-2017, significant decrease in land use for forests, bushes and grazing were exhibited across all the three sites. In contrast, cropland use in all three sites has increased significantly over approximately the same time period (Berihun *et al.,* 2018). Likewise, Yibeltal *et al.* (2019) find higher rates of land degradation in Guder and Aba Gerima than in Debatie. According to the authors, the larger land degradation problem in Guder and Debatie is due to their longer history of cultivation and human settlement.

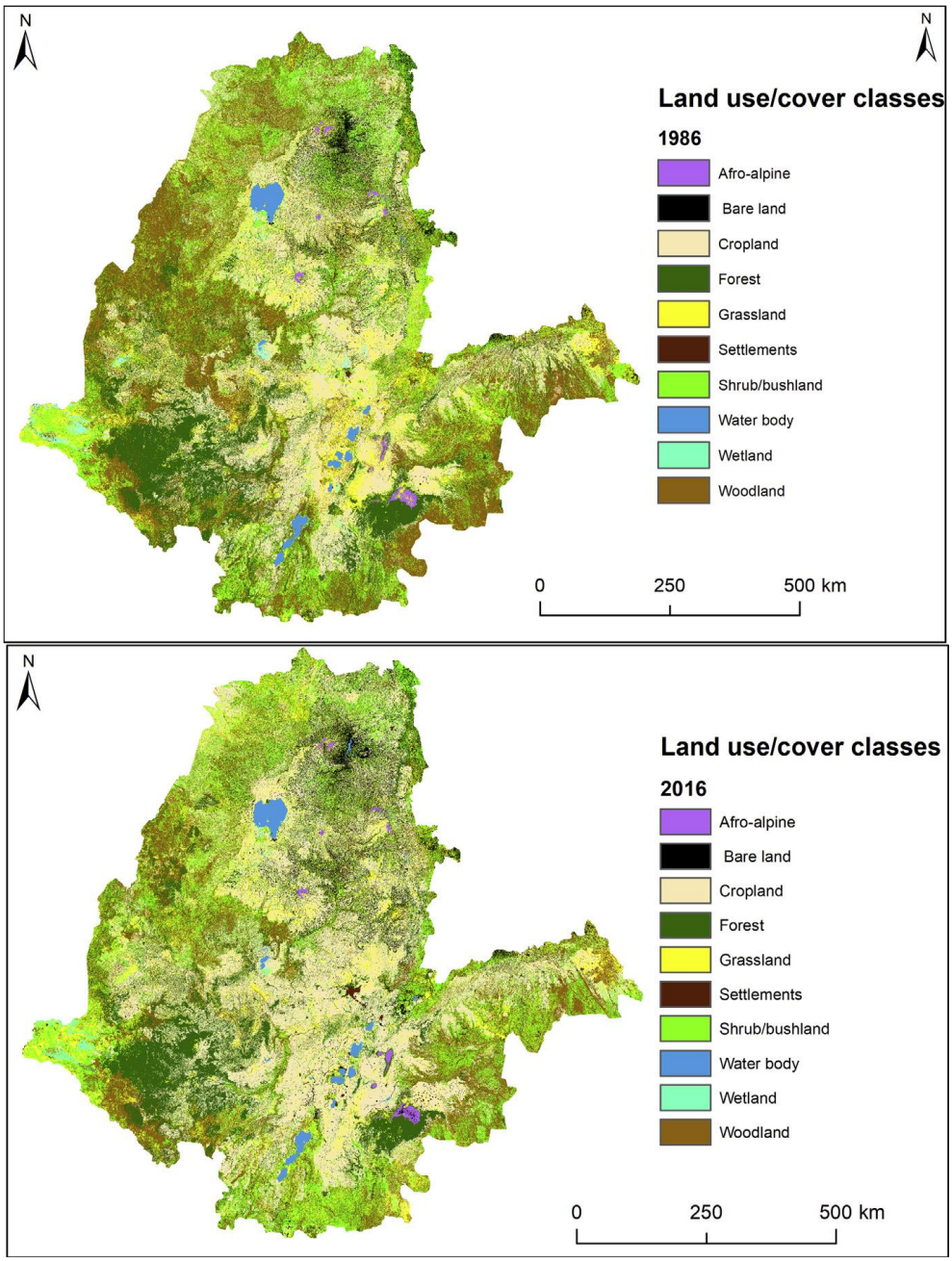
Shiferaw *et al*. (2019) used Landsat Satellite data to study LULC dynamics in Afar Regional State, Ethiopia, over the period from 1986 to 2017. According to the authors, the amount of grasslands, bare lands and bush-shrub-woodlands decreased between 1986 and 2017. In contrast, the authors also found that the annual rate of *Prosopis* expansion increased by 31,127 hectares. However, the dynamics of land use vary within Afar region. For example, in Southern Afar region, the amount of bush and shrubland has increased 114.3 percent between 1985 and 2015 (Mekuyie *et al.,* 2018).

Degife *et al.* (2018) examined land use changes for Gambella Regional State, Ethiopia over the period from 1987 to 2017. The authors find that large-scale farms increased from 202 to 747 square kilometers between 1987 and 2017. Over the same period, the land share of small-scale farming first increased by 9.17 percent between 1987 and 2000 and then declined by 7 percent between 2000 and 2017. Moreover, the region experienced an extensive environmental degradation caused by the conversion of savannah/tropical grasslands into agricultural farmland (Degife *et al*., 2018). In Somali Regional State (Gode district) of Ethiopia, agricultural settlement and the amount of bare land decreased over the 1973 to 2012 time period (Worku *et al.,* 2018). According to the authors, the amount of woody shrubland and grassland has significantly increased over the same time period. As the authors explained, the main drivers of the observed LULC change are drought, overgrazing, erratic rainfall and charcoal production.

Using Landsat images from the years 1985, 1995, 2005, and 2015 for Bale Mountain Eco-Region in Ethiopia, Hailemariam *et al.* (2016) find that forest land decreased by 123 hectares, whereas farmland increased by 292,294 hectares between 1985 and 2015. According to the authors' estimate, the resulting above-ground carbon stock removed from forest and shrubland was more than 24 million tons.

However, despite the multiplicity of studies on LULC change in the country, there is scanty evidence of LULC change using wider regional or national scale data (see Gebresellasie *et al.,* 2016 and Kassawmar *et al.,* 2018 for exceptions). Kassawmar *et al.* (2018) studied LULC changes over three decades, from 1986 to 2016, for Ethiopia's rainfed agricultural area (RAA) and covered most of the country's regions (see Figure A1 in Annex). Based on their LULC data between 1986 and 2016 (see Figure 1), they find that the majority (about 40 percent) of the LULC of Ethiopia's highland RAA remains stable and that the central and (smaller) eastern parts of the RAA, which are intensively cultivated highland, appear to be reversing, that is, regenerating.

Figure 1: LULC of Ethiopia's RAA for 1986 and 2016



Source: Kassawmar *et al*. (2018).

Nevertheless, deforestation and forest degradation are prominent in the lowlands, appearing dense in the western (mainly lowland) part of the RAA. As can be observed, these types of LULC transformation become denser as one moves from south to north in the western part (Kassawmar *et al*., 2018).

2.3 Causes and impacts of land degradation

As stated earlier, land degradation has always been a major environmental problem in Ethiopia that has serious consequences on the social and ecological setting of the country (Hurni *et al*., 2010; Berry, 2003). With continuous population growth, the problem is likely to be even more important in the future. Land degradation is usually considered one of the major causes of low agricultural productivity, which then increases the challenges of food insecurity and persistent rural poverty. Land degradation also reduces the availability of potable water and biodiversity losses. There could be several factors that cause land degradation. While Berry (2003) argues that the cause of land degradation is due to the interplay between the natural ecosystem and the human social system, the World Metrological Organization (2005), in contrast, lists several causes of land degradation.[5]

Different forms of land degradation, including water and wind erosion, and physical and biological soil degradation are observed in Ethiopia. Although land degradation in Ethiopia is caused by the interaction of many forces, the main factors causing land degradation in Ethiopia could be classified as proximate and interacting causes (Zelleke *et al*., 2010; Amede *et al*., 2001; Temesgen *et al*., 2014). Some of the direct causes of land degradation include massive forest clearance, the exploitative crop cultivation practices, the burning of dung, and removal of crop residues as well as overgrazing. On the other hand, poverty, insecure land tenure, economic policies, population growth and weak natural resource management techniques also play a role in the land degradation process. Topography, soil types and agro-ecological parameters are additional factors causing land degradation.

Clearing of forests and woodlands: Forest disturbance can lead to considerable acceleration of land degradation. The excessive removal of vegetative cover is one of the major driving forces behind land degradation in Ethiopia. Due to the rapidly growing population and increased demand for food, grazing land, and energy requirements, vegetative cover is removed leading to soil surface exposure. Deforestation is an acute problem in Ethiopia due to a host of reasons, such as increased energy and construction needs, agriculture and livestock production, etc. Most of the energy supply in Ethiopia depends on biomass energy sources mainly coming from fuelwood. According to FAO (2015) statistics, forest cover was between 35 and 40 percent in the 1990s but has declined to less than 12 percent in 2010. Forests provide effective protection against surface erosion and influence slope stability, as tree root systems contribute to soil strength by providing additional soil cohesion.

Crop cultivation practices: The subsistence farming system practiced in Ethiopia is among the main factors causing land degradation. Annual crop production with an emphasis on small seed crops that require fine tillage is the major source of income for farmers in Ethiopia. The emphasis on annual rather than on perennial crops implies that land cover is low and multiple ploughings of the soil to make fine seedbeds intensifies the problem. The low level of irrigation also increases the dependency on rainfall, which exposes the soil to incipient rains. Due to a shortage of land and alternative livelihood systems, farmers in Ethiopia are forced to cultivate lands that have slopes of more than 60 degrees with shallow and stony soils prone to erosion.[6] The expansion of cultivation into marginal lands is also another major problem.

Using dung and crop residues for fuel: As fuelwood demand has increased, the use of dung and crop residues as fuel has also intensified in Ethiopia. The use of animal dung and crop residue for fuel will compromise the potential use of these materials as inputs to maintain soil fertility. The use of animal

[5] The causes of land degradation can be classified into biophysical factors such as unsuitable land use (land use for the purpose of which is environmentally unsuited for sustainable use), socioeconomic factors such as poor land management practices, land tenure, marketing, institutional support, income and human health, and political factors such as lack of incentives and political instability.

[6] Slopes larger than 30 degrees should not normally be used for agricultural purposes, but rather allocated to natural vegetation or forestry.

dung as fuel instead of replenishing the soil is estimated to reduce agricultural GDP in Ethiopia by about seven percentage points (IFPRI, 2010).

Overgrazing of pasture lands: Livestock plays a critical role in the Ethiopian farming system in providing draught power and food. As a result, farmers like to maintain large herd sizes, which causes an overgrazing of rangelands. Overgrazing is a serious problem, particularly in cereal-producing zones of the country. Livestock density data show that current stocking rates are well above optimum rates.

There are also several additional indirect factors contributing to the land degradation problem. Poverty and limited financial capacity limit farmers' options in dealing with adverse conditions. Uncertain land tenure arrangements leading to low investments into the land have also contributed to land degradation. Weak policies, the implementation capacity and rapid population growth are additional factors contributing to the land degradation problem.

The negative impact of land degradation on economic and social development is likely to continue in the future in Ethiopia due to the rapid population growth and will be manifested in many different ways. Among the impacts of land degradation, loss of nutrients due to topsoil erosion, loss of livestock-carrying capacity, loss of environmental services, and reduced food security leading to increased poverty and malnutrition are the major ones. Some attempts have been made to estimate and quantify the cost of land degradation in Ethiopia (Bojo and Cassells, 1995; Berry, 2003; Sonnenveld, 2002; Melaku, 2013; Shiferaw and Holden, 1998). For instance, Melaku (2013, cited in Gebereselassie, 2016) argues that about 70 percent of Ethiopia's highland population and an area of over 40 million hectares are affected by land degradation, indicating the scale and extent of the problem confronting the country. Berry (2003) also estimated the direct losses of productivity from land degradation in Ethiopia to be at least 3 percent of agricultural GDP.[7]

Land degradation threatens the food security of the poorest and most food insecure people of the country (Gashaw *et al* 2014; 2005; Kirui, 2016). It is also linked to vulnerability to climate change and increased poverty. Poverty is exacerbated by land degradation, because it reduces the availability of fuelwood, construction materials, food and medicinal plants and increases the demand for labour to collect these items. It is influenced by the concentration of rural populations on degrading land whose productivity is substantially eroded. Amede *et al*. (2001) have shown that the Ethiopian highlands are particularly affected by the challenges of deforestation and land degradation, which aggravate the food shortages caused by drought. As a result, Ethiopia has become a net food importer. Hence, eradicating poverty and food insecurity without adequately addressing land degradation could be highly unsuccessful.

The most common form of land degradation in Ethiopia is soil erosion. Although the estimates vary widely, studies have shown that Ethiopia loses billions of birr in the form of soil erosion (Dubale, 2001; FAO, 1986; Sonneveld *et al*., 2002; Zelleke *et al*., 2010; Bojo and Cossells, 1995). For instance, the FAO (1986) estimated that about 27 million hectares of land or almost 50 percent of the highland area in the mid-1980's was significantly eroded. The soil loss affects the types of plant that are grown, the availability of water and the biodiversity of the area (Berry, 2003; Mulugeta, 2004). In addition, land degradation also adversely affects health, economic activities such as ecotourism (UNCCD 2004) and water quality. Land degradation also increases migration rates due to the decline in the fertility of land that can ultimately no longer support the livelihoods of the rural population (Sonneveld *et al*., 2002). Moreover, it increases runoff, reduces infiltration resulting in flooding, reduces livestock productivity due to reduced grazing land and leads to the loss of nutritious plant and grass species (Desta *et al*., 2000; Bezuayehu *et al*., 2002; Hagos *et al*., 1999).

Like in other developing countries, land degradation also impacts men and women in Ethiopia differently, mainly due to the unequal access to land, water, credit, extension services and

[7] Sonneveld (2002) estimated the loss of agricultural value due to land degradation between 2000 and 2010 to be about $US 7 billion.

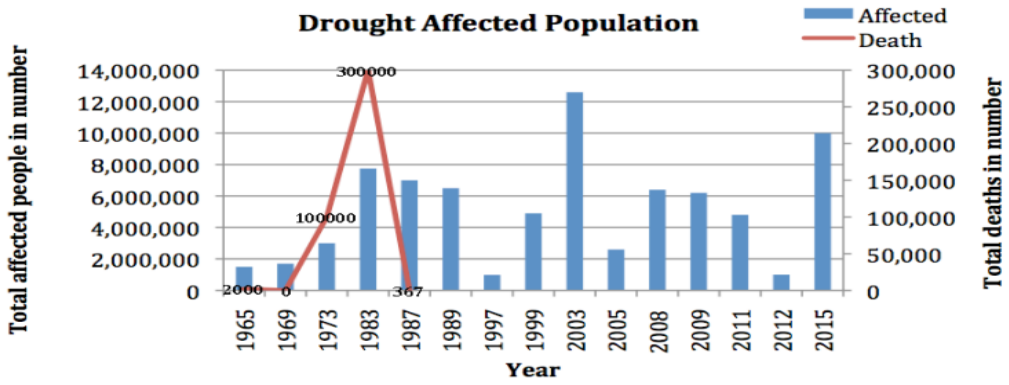
technology. Women and girls are forced to engage in more time-consuming, labour-intensive but unpaid or poorly remunerated work and household responsibilities, including producing food and procuring water when land is degraded and becomes unproductive (Davis *et al*., 2015).

3 Observed and projected trends of climate change

3.1 Observed and projected trends

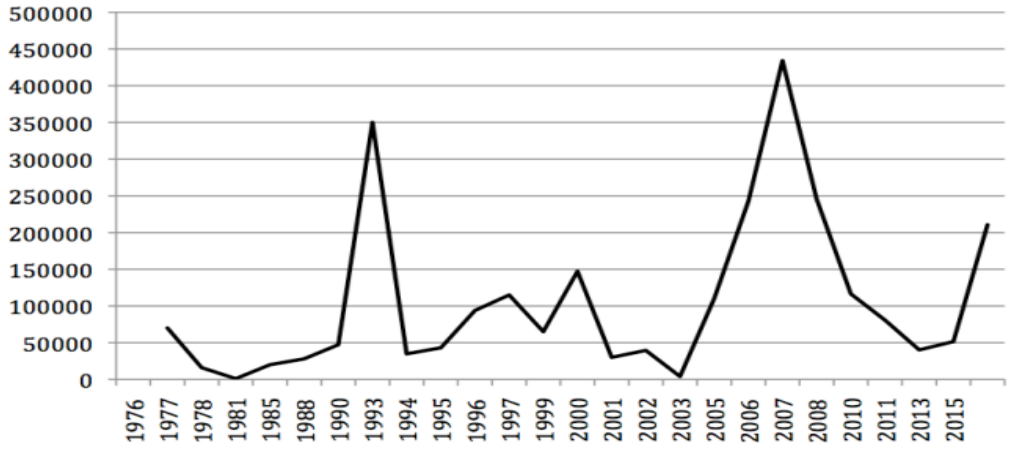
Climate change has become one of the development challenges of the whole world. The effect of climate change is much more pronounced in developing countries due to their low coping mechanisms. Ethiopia is also one of those countries in sub-Saharan Africa which is (will be) affected adversely by climate change, thereby undermining environmental, social and economic development efforts. The effect of climate change is visible in Ethiopia in the changes observed in the environment and natural resources. Ethiopia's recent history is associated with major natural and man-made disasters that have affected many Ethiopians. For instance, recurrent drought, famine and recent floods have caused major disasters that have affected millions of people in the country (see Figures 2 and 3). These climate-related disasters have significant negative impacts on agriculture, rural livelihoods, food security and economic development. Moreover, it is predicted that changes in climate will continue to cause recurrent droughts and heavy rainfall in different parts of Ethiopia, reducing the amount of land that can be used for agriculture and overall decreasing crop productivity.

Figure 2: Number of Population Affected by Major Drought in Ethiopia



Source: Federal Democratic Republic of Ethiopia (FDRE, 2019).

Figure 3: Number of Population Affected by Flood in Ethiopia

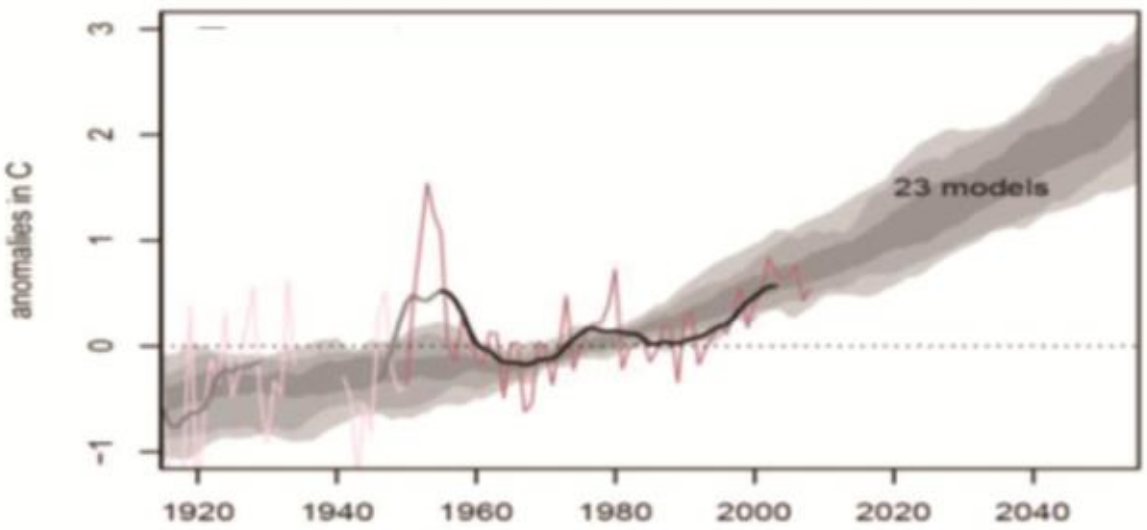


Source: Federal Democratic Republic of Ethiopia (FDRE, 2019).

According to reports from the National Metrological Agency (NMA, 2007), Ethiopia is extremely vulnerable to drought and other natural disasters such as floods, heavy rains, frost and heat waves. Ethiopia's geographical location and its topography in combination with low adaptive capacity entail a high vulnerability to adverse impacts of climate change. Huge fragile highland ecosystems that are currently under stress due to population pressure and associated socio-economic problems exist in Ethiopia. A significant part of the country is also dry sub-humid, semi-arid and arid. There are different mechanisms through which the effect of climate variability and climate change are manifested.

Increased temperatures: Increase in temperature is linked to more intense heat waves and higher rates of evapotranspiration. Warmer temperatures and increased evapotranspiration can exacerbate tensions that exist between agricultural and livestock interests as well as other uses of water, especially during the dry season. Ethiopia had experienced both warm and cool years over the last 55 years (see Figure 4), although recent years have been warmer as compared to previous years (NMA 2007).

Figure 4: Observed changes in temperature in Ethiopia



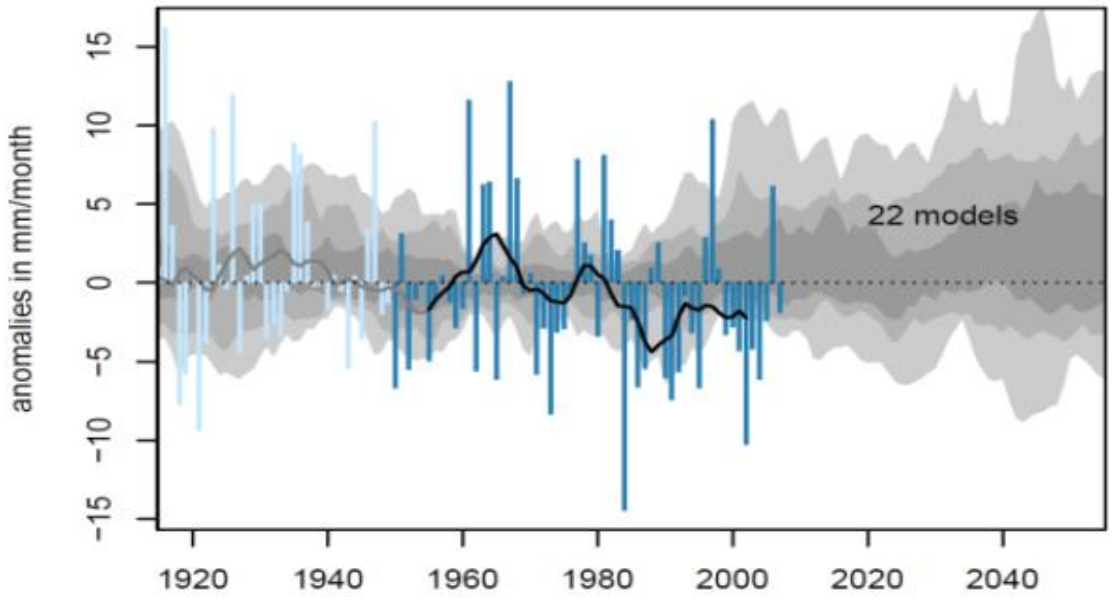
Source: Schneider *et al*. (2008).

Over the last several decades alone, the minimum temperature in Ethiopia has increased by roughly 0.4° C and is projected to continue increasing over the next few decades (Kassahun, 2008; Mengistu, 2008; Brohan *et al.,* 2006; Mengistu and Mekuriaw, 2014; IPCC, 2014). The increases in temperature can affect many aspects of local economic development and agricultural productivity.

Changes in rainfall patterns, including decreased reliability and less predictability: Annual and seasonal rainfall distribution is highly variable in some parts of the country (Bewket, 2009). Historical data indicate that rainfall is increasingly becoming erratic, with marked seasonal deficits when compared to long term past averages (see Figure 5). Both *belg* and *kiremt*[8] rainy seasons are contracting, reducing the amount of seasonal rain available for crop production (Funk *et al.,* 2012). The irregularity and unreliability of the rains will have significant impacts on food security, as rainfall patterns tend to be positively correlated with cereal yields and negatively correlated with food prices.

[8] Belg is the short rainy season in February while Kiremt is the main rainy season starting from June to September.

Figure 5: Observed changes in precipitation in Ethiopia



Source: Brohan *et al*. (2006).

Recurrent droughts: Recurrent droughts and recent floods are among the main climate hazards in Ethiopia (see Figure 4). Over the years, several extreme droughts have occurred in Ethiopia that have claimed the lives of millions of Ethiopians (Mahoo *et al.,* 2013). Indeed, the greatest loss of life associated with drought occurred in 1984, 1974 and 1973. More recently, in 2002, about 14.2 million people (over 20 percent of the total population) were affected by drought although there was major loss of life (World Bank, 2007). The main impacts of drought include crop damage, loss of pasture and water sources, loss of animals, hunger, disease outbreaks, asset depletions, malnutrition and migration. Even today, drought remains one of the key drivers of food insecurity in Ethiopia.

Flooding: In addition to the above-mentioned climate-related hazards, flooding, which causes crop and infrastructural damage, is also now becoming more frequent in Ethiopia. Flooding also contributes to farmland degradation and soil erosion as well as loss of human and animal life. Although floods have not been common in Ethiopia in the past, devastating floods occurred in 1997 and 2006, which claimed the lives of many people and caused significant economic costs (Tarhule, 2005, Conway *et al.,* 2009; EMDAT, 2009). The 2006 flood, for example, claimed 719 human lives, displaced about 242,000 people, severely damaged infrastructures and houses, and caused property loss worth millions of USD across the country (Tadesse and Dagnachew, 2006). Flood hazard is increasing in the highland areas due to changes in land use/land cover, rainfall patterns and drainage.

Future climate projections also show that Ethiopia is likely to continue experiencing various kinds of climate-related hazards, which will have significant impacts on the natural and human systems. Some global climate models predict that climate variability will continue to cause a high degree of uncertainty, especially around changing rainfall dynamics, and suggest an increase in precipitation in both the dry and wet seasons. While climate models project a general drying trend across the south and southeast of the country with a possible wetting trend in the north (USAID, 2015), other models show that precipitation is expected to decrease in the northern regions, while southern areas could see an increase (World Bank, 2011). Climate projections show continued warming, but very mixed patterns of rainfall change (Conway and Schipper, 2011). Other studies with more detailed regional climate models, however, indicate that the expected precipitation change is uncertain (NMA, 2008; Schneider *et al*., 2008).

While the different model projections give mixed results with regard to changes in precipitation, all projections clearly indicate that temperatures will continue to increase, and that these will increase

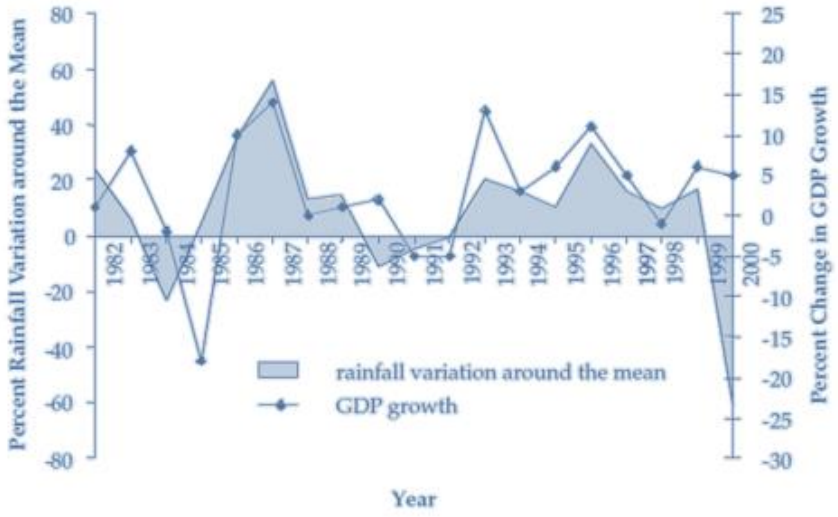
evaporation and soil moisture deficits with serious implications on agriculture and other related activities both in the near and the long term, which will not be offset by any of the projected changes in rainfall dynamics (NMA, 2008; Brohan *et al.,* 2006; Schneider *et al.,* 2008).

The impacts of these changes are already significant, not only in human costs but also in economic and financial terms. The development gains made over the past few years as well as future development interventions will be under risk. Furthermore, different strategies will have to be developed for different regions of the country as the impacts of climate change will not be uniform across regions.[9]

3.2 Impacts of climate change

Ethiopia is ranked globally as one of the most vulnerable countries with respect to climate change, especially within its agriculture, health and water sectors. Rising average temperatures, erratic rainfall, and other extreme weather events are expected to threaten agriculture and food security, health, water availability, and the economic development progress that the country has made in recent years and have hampered the country's economic growth and effort to move out of poverty. Several World Bank and other studies, some using CGE frameworks, have indicated that climate change had exerted significant impacts on the overall economic growth in Ethiopia in the past by reducing GDP growth rates significantly and will continue to compromise economic growth rates (World Bank, 2008; World Bank, 2010; World Bank, 2015; You and Ringer, 2010; Asaminew *et al*., 2013; Mideksa, 2010; Evan, 2012) (see Figure 6).

Figure 6: Relationship between rainfall variation and GDP growth



Source: World Bank (2006).

Impact of climate change on agriculture: Climate change, particularly due to the increased frequency of heat stress, droughts and floods, negatively affects the agriculture sector through different channels[10]

[9] Vulnerability will depend on livelihood type and exposure to risk, both of which are highly variable even within small/local regions.

[10] Due to an increase in temperature, climate change will affect the agriculture sector, among others, by (i) a reduction in crop yields and agricultural productivity, (ii) increased incidence of pest attacks that are detrimental to crop and livestock production, (iii) limiting the availability of water exacerbating drought periods, (iv) reduction in soil fertility, (v) low livestock productivity and high production cost due to its effect on

(IPCC, 2007). As pointed out earlier, the main climate hazards in Ethiopia are associated with rainfall variability, including amount, timing and intensity. Since rainfed smallholder agriculture is the dominant economic sector in Ethiopia, climatic variables like temperature, precipitation and humidity will have direct impacts on its productivity.[11] The recurrent droughts frequent in Ethiopia have caused frequent crop failures as crop production in the country is highly correlated with rainfall patterns and variability. Studies have confirmed that with higher vulnerability and decreased resilience to climate change-induced impacts, Ethiopia is projected to experience a significant decline in total agricultural output in the years to come (Kreft *et al*., 2015; Asaminew, 2009; Nelson *et al*., 2009; Deressa and Rashid, 2009; Deressa *et al*., 2008; CEEPA, 2006; Gebreegziabher *et al*., 2014). Of course, the impact of climate change on the productivity of major crops varies with crop type, location and future time span considered (Tesfaye *et al*., 2015a).

Impact of climate change on food security: Climate change is a significant contributing factor to food insecurity due its effect on agricultural production, either by reducing crop yields, increasing land degradation or lowering water availability. Historical records in Ethiopia show that the erratic rainfall patterns and frequent droughts have disrupted crop and livestock production and exacerbated food insecurity and famine in many parts of Ethiopia (Conway and Schipper, 2011; Conway, 2000; Hulme *et al*., 2001; Seleshi and Zanke, 2004; Thornton et al., 2006; Demeke *et al*., 2011; Rosell, 2011; World Bank, 2006). For instance, a study by Tesfaye *et al*. (2015) showed that the number of food insecure people in Ethiopia would increase by up to 2.4 million people by 2050 as a result of the impact of climate change. In addition to causing food insecurity, climate change will also increase the malnourishment of poor people (Gregory *et al*., 2008; UNFCCC, 2009).

Impact of climate change on human health: Climate change also affects the health and wellbeing of many people in Ethiopia. Because of increasing surface temperature, malaria is expected to migrate to higher altitudes and lengthen the transmission period of major vector-borne diseases as well as alter their geographic range (Transfer *et al*., 2003). For example, according to an NMA (2007) report, climate change is projected to cause encroachment of malaria from lower altitudes to higher altitudes of the country and will affect labour availability at the household level while increasing the health expenses of the family. Changes in precipitation and seasonal variability have also increased incidences of flash flooding, which will disrupt the supply of drinking water and lead to pollution, which, in turn, increases the risk of exposure to water-borne pathogens. For instance, an epidemic of cholera occurred following extreme floods in 2006, leading to widespread illness and loss of life.

Impacts of climate change on water resources: The reduction of available water for crop and livestock production as well as for domestic human use is also a major impact of climate change. Rising temperature and decreasing rainfall have worsened drought conditions, leading to water scarcity, which results in decreased access to drinking water. More frequent and longer periods of drought reduce the amount of run-off into rivers, streams and lakes. In addition, groundwater recharge rates are insufficient to meet sustainable demand, leading to decreasing water quality. Studies on the impact of climate change on water resources have shown that there will be an increase in evapotranspiration leading to water scarcity (Getnet *et al*., 2014), and a decrease in soil water, ground water and stream flows (Haregeweyn *et al*., 2016; Nigatu *et al*., 2016) both by 2050 and the end of the century.

Other impacts of climate change: Climate change-induced problems also lead to conflict, forced migration and malnutrition. Conflicts over the use of resources (such as on water as well as farm and grazing land) increase significantly in the face of climate change. Similarly, children might drop out of school because their labour is needed for water collection from faraway locations during times of

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feed and fodder availability, (vi) increased tension/conflict, and (vi) outmigration and low availability of labour for agriculture.

[11] According to Nelson *et al.* (2009), the impacts of climate change on agriculture and human well-being include: i) biological effects on crop yields; ii) impacts on prices, production and consumption; and iii) impacts on per-capita calorie consumption and child malnutrition.

water scarcity. Climate change also affects nutrition through various causal pathways that impact food security, sanitation, water and food safety, health as well as maternal and child healthcare practices.

4 Technological, socioeconomic, and policy actions for sustainable land management and climate change adaptation and mitigation

Rural households in general, and smallholder farmers in particular, are not simply passive observers of the risks posed by climate change and land degradation. In fact, as in other developing countries, Ethiopian smallholder farms and the Government of Ethiopia use several strategies, including farm and non-farm diversification, agricultural practices, migration, and macro-level programs and policies to minimize the negative impacts of climate change and degradation of natural resources on livelihoods. In what follows, we describe some selected examples of the main responses adopted by farmers and policymakers in the country.

4.1 Technological responses categorized by land use types

Ethiopian farmers have a long history of applying various measures to adapt to changing climate and manage degradation of natural resources including land. This section attempts to identify and describe some of the main technological responses used by Ethiopian farmers according to land use type.

4.1.1 Croplands

a. Expanding irrigation

Irrigation development is a policy priority in Ethiopia. Recently, the Government of Ethiopia has adopted a National Smallholder Irrigation and Drainage Strategy (NSID) to guide the country's efforts to transform the country's agriculture through irrigation development (MOANR *et al.,* 2016). In fact, promoting and supporting development of smallholder irrigation has received increased policy attention from the Government within Ethiopia's CRGE strategy (FDRE, 2011). To encourage a wider dissemination and adoption of irrigation technologies, the Ethiopian Ministry of Finance has recently (in May of 2019) decided to remove almost all duty tax on irrigation, mechanization and animal feed equipment and technologies (IWMI, 2019).

At present, about 15 million hectares of Ethiopia's total cultivable land (i.e., 30-70 million hectares) is under cultivation (Teshome *et al.,* 2018). Estimates of potentially irrigable land in Ethiopia varies by source (Table 1). For example, according to NSID (MOANR *et al.,* 2016), Ethiopia has 11.1 million hectares that can be irrigated through surface irrigation. Irrigation has expanded relatively rapidly from a small base in recent years. For example, the amount of land under small-scale irrigation increased by almost 1.5 million hectares under Ethiopia's First Growth and Transformation Plan (GTP I) and reached about 2 million by 2015. The target for the second Growth and Transformation Plan is to cover an additional 1.75 million hectares and to ensure that 80 percent of Ethiopian farmers have at least one source of water for irrigation (MoANR *et al.,* 2016).

Despite the high potential of irrigation, most (90-95 percent) of Ethiopia's annual food production is still produced during the rainy season (Mario *et al.,* 2010 cited in Worqlul *et al.,* 2017). Furthermore, irrigation in Ethiopia is used for the production of a select group of crops. According to Mendes and Paglietti (2015), existing irrigation schemes in the country are mostly used for the production of high-value crops. More specifically, the authors indicated that almost all industrial crops (e.g. cotton, sugarcane, fruits) and some 37 percent of vegetables in Ethiopia are produced through irrigation.

Tab 1: Ethiopia's irrigation potential (in million hectare) estimated by different sources

Source	Surface Water	Ground Water	RWH	Total
IWMI 2010	3.7	1.2	0.5	5.4
NSID	4.3	4.7	4.4	11.1

(NSID according to MoANR *et al.,* 2016).

Irrigation development in Ethiopia is hindered by several factors. A recent review of the irrigation literature by Nakawuka *et al*. (2018) demonstrates that expansion of smallholder irrigation in Ethiopia is hindered by land tenure issues, limited access to markets including finance and credit, poor irrigation water management and limited access to appropriate irrigation technologies. Despite these challenges, however, ample opportunities exist for expansion of smallholder irrigation in Ethiopia (Nakawuka *et al*., 2018). More specifically, as the authors state, Ethiopia in particular and East Africa in general has "high untapped irrigation potential; rainwater harvesting to improve water availability; high commitment of national governments, NGOs and donors to smallholder irrigation expansion; low cost irrigation technologies adaptable to local conditions; traditional schemes rehabilitation; growing urbanization; and increased use of mobile phones that can be used to disseminate information" (Nakawuka *et al*., 2018, p. 1).

b. Application of water-efficient irrigation methods

Irrigation water is a scarce agricultural resource. As such, efficient irrigation methods are required to maximize yield out of the available water for crop production. Under the context of climate change, effective and efficient irrigation water management and use of irrigation is required for sustainable agricultural production. However, about 56 percent of the total countrywide irrigation schemes in the country are old-style surface irrigation (Awulachew *et al*., 2016 cited in Teshome *et al.*, 2018), which is characterized by very low irrigation performance (Teshome *et al*., 2018). Another source of inefficiency in irrigation water use in Ethiopia is related to the current agricultural extension system as described in MoANR et al. (2016, p. 80): "--In Ethiopia, crop water requirement and irrigation scheduling advisory service is provided through the DA system. SMEs[12] and DA's do analysis on crop water requirement and schedule based on the data they get from FAO website. This way of advisory is not much effective as a single DA reaches a large number of farmers. A single farmer does not have the access to know the crop water requirement and schedules that are specific to its farm." As a way forward, the MoANR *et al*. (2016) intends to develop ICT-based advisory on crop water requirements and schedules to improve the efficiency of irrigation water usage by farm households. However, a recent study (Worqlul *et al*., 2017) recommends adoption of water-saving irrigation practices (e.g. drip irrigation systems) to transform Ethiopia's agriculture through irrigation.

c. Rainwater harvesting

As in other African countries, food production in Ethiopia is constrained by the risk of erratic and unpredictable rain. As can be seen in Table 1, the Government of Ethiopia recognizes the importance of rainwater harvesting as an important source of water for irrigation in the country. In this case, rainwater could be collected using roof water harvesting and runoff water harvesting techniques. Cognizant of its high potential to overcome the problem of erratic rains and frequent drought-incidence, rainwater harvesting has been widely promoted by the Government since the early 2000s (MoANR *et al*., 2016; Wakeyo and Gardebroek, 2013). Apart from its role as a drought risk management tool, rainwater harvesting tends to increase adoption of other yield-increasing inputs such as chemical fertilizers by smallholder farmers in Ethiopia (Wakeyo and Gardebroek, 2013). However, as the authors have stated, adoption and usage of rainwater harvesting still remains low in Ethiopia.

[12] SMEs stand for subject matter experts.

d. Crop diversification

Crop diversification is a widely used means of managing climate change risks and land degradation in Ethiopia (Di Falco and Chavas, 2009). In this respect, diversifying the crops grown by farmers is seen not only as a strategy to diversify risks but also as an important instrument for ensuring food and nutrition security, generating employment, reducing rural poverty, and managing environmental and ecological problems (FAO, 2012). Recent empirical studies conducted in Ethiopia (e.g. Michler and Josephson, 2017; Di Falco and Veronesi, 2013; Bezabih and Sarr, 2012; Di Falco and Chavas, 2009) provide supporting evidence for some of these outcomes. Michler and Josephson (2017) find that Ethiopian farm households who grow a large number of crops are less likely to be poor. More specifically, according to the authors, crop diversification significantly reduces the probability that a non-poor farm household falls into poverty and that a poor farm household will remain in poverty. Di Falco and Chavas (2009) also report that crop diversity has enabled Ethiopian farmers to deal with crop failure caused by drought and other environmental problems. However, despite its multiple economic and environmental benefits, not all farmers are able to diversify their crops. Benin (2004) shows that farm households with larger farms are significantly more likely to grow a larger number of cereals as compared to those with smaller farms.

e. Adoption of drought-tolerant crops and crop varieties

Crop yields are significantly correlated with soil moisture and adequate rainfall. Frequent drought occurrence along with inadequate soil moisture has become a major source of risk to crop production in Ethiopia. One means of managing drought risk in agriculture is to plant drought-tolerant crops and crop varieties. To this end, the Government of Ethiopia has long supported the country's agricultural research system to develop drought-tolerant crop varieties adaptable to the wide range of agro-ecologies in the country. In fact, a study commissioned by the African Union (AU-SAFGRAD, 2013) indicates that many drought-tolerant crops and crop varieties (e.g. sorghum, teff, maize, wheat, beans, millet, etc.) have been developed and released throughout the country. According to the study, the CGIAR centres and universities played important roles in the development of the different drought-tolerant and climate change-resilient crop varieties in the country.

f. Conservation agriculture

Conservation agriculture (CA) is proposed as an environmentally sustainable production system (FAO, 2015). Under climate change, CA can help increase agricultural productivity by improving soil fertility and conserving soil moisture. In Ethiopia, CA has been promoted by non-governmental organizations and the private sector as a climate-smart agricultural activity (Jirata *et al.*, 2016). As the authors argue, the larger-scale promotion of CA in Ethiopia is constrained by a lack of common understanding among key stakeholders and other social and environmental issues, including complete removal of crop residues and widespread open grazing. Despite its economic and environmental benefits, the analysis of the farmer-level costs and benefits of CA is still limited. Kassie *et al*. (2009) have shown that the adoption of conservation agriculture practices has increased crop productivity in Tigray, Ethiopia. However, the adoption of CA is hindered by small farm size, lack of information and technology, and labour scarcity. The authors also find that adoption of conservation agriculture practices (e.g. conservation tillage) is significantly lower among female-headed households.

g. Agroforestry

Under the context of land use threatened by the issues of rapid deforestation and land degradation, investment in agroforestry can help rural households meet various development (e.g. food security, poverty reduction, employment, domestic energy, and insurance against risks), and environmental (e.g. reduced flooding, watershed protection, soil and water conservation) goals (Scherr, 1995; Current *et al*., 1995). Technically speaking, agroforestry involves the production of crops or livestock on the same plots as forest trees.

Agroforestry has received much government attention as a practice to enhance the climate-resilient green economy in the country (FDRE, 2016). Agroforestry practices show significant spatial and temporal variation in Ethiopia. According to Bishaw and Abdelkedir (2003, cited in Beyene *et al.,* 2019), the most common types of agroforestry practiced in Ethiopia are scattered trees in croplands, home gardens, alley cropping, keeping riparian vegetation, and enclosures. For example, farmers in Konso, Omo, Burji, Sena and Mele districts of SNNPR, Ethiopia, traditionally interplant the moringa tree with sorghum and other crops (JIrata *et al*., 2016). According to the authors, Ethiopia's Ministry of Agriculture has identified and started promoting the tree for wider adoption as an important agro-forestry technology under the context of climate change.

Despite its beneficial effects, micro-level studies of household adoption of agroforestry practices are limited in Ethiopia. Using cross-sectional data from three regions of Ethiopia (i.e., Amhara, Oromia, Tigray, and SNNPR), Beyene *et al.* (2019) show that farmer-level adoption of agroforestry is strongly associated with human capital, land tenure, and location factors. More specifically, the likelihood of agroforestry adoption has a strong and positive association with land size and a strong and negative relationship with proximity to town and land tenure insecurity. The probability of agroforestry adoption is significantly higher in Oromia and Tigray regions as compared to SNNPR.[13] Age of household head has a strong inverted "U-shaped" relationship with the probability of agroforestry adoption.

4.1.2 Rangelands

Livestock production in Ethiopia highly depends on natural resources such as the rangelands that cover about 65 percent of the land surface of the country (Bolo *et al.,* 2019). Among others, rangeland degradation is a growing challenge for sustainable livestock production in the country (Dunkan *et al*., cited in Mekuria *et al.,* 2018; Bolo *et al.,* 2019). Both anthropogenic and natural factors are the main causes of degradation of rangelands in Ethiopia (Mussa *et al.,* 2016 cited in Bolo *et al.,* 2019). Apart from rangeland degradation, expansion of invasive species has become a threat to rangeland productivity in Ethiopia (Tilahun *et al.,* 2016; Mehari, 2015).

As such, sustainable livestock production requires proper rangeland management practices in order to minimize rangeland degradation caused by over-grazing and the expansion of invasive plant species and bush encroachment. To this end, the importance of applying rotational grazing and addressing invasive bush encroachment are discussed below.

a. Rotational grazing

Abandoning uncontrolled free grazing and shifting to rotational grazing are necessary actions to reduce the rising degradation of rangelands in Ethiopia. However, despite their negative consequences, uncontrolled and open grazing practices are widespread and managed rotational grazing remains low, especially in the highland areas of Ethiopia (Mekuria *et al.,* 2018; Gebremedhin *et al.,* 2004).

b. Addressing invasive plant species and bush encroachment

Prosopis juliflora is a weedy invasive plant species that poses a major threat to the rangeland resources of Ethiopia (Tilahun *et al.,* 2016; Mehari, 2015). Recent empirical studies in Afar region of Ethiopia show that *P. juliflora* has been rapidly expanding since its introduction in the 1970s (Ilukor *et al.,* 2016). Although the full negative impacts of *P. juliflora* have not been systematically studied, researchers who have conducted case studies across the affected localities (e.g. Ilukor *et al.,* 2016; Mehari, 2015; Tilahun *et al*., 2016) find that *P. juliflora* is negatively affecting pastoralists' livestock production and the fragile ecosystems they depend upon. Among others, the negative impact of *P. juliflora* stems from its negative effects on pasture availability, peoples' and livestock mobility, and

[13] SNNP stands for Southern Nations, Nationalities and Peoples' region.

the health of people and livestock (Mehari, 2015). However, the effects of *P. juliflora* are not all negative. In fact, as reported in Bekele *et al.* (2018) and Ilukor *et al.* (2016), *P. juliflora* has some socioeconomic benefits such as serving as a source of domestic fuel and household income (i.e., by selling it as firewood and charcoal).

4.1.3 Forests, woodlands and shrublands

The Government of Ethiopia has a longstanding history of tree plantation (Lemenih and Kassa, 2014). Recent years have seen a renewed commitment of the Government to tree plantations. Among others, the country's CRGE strategy aims to afforest two million hectares and reforest one million hectares by 2030, while sustainably managing four million hectares of forests (FDRE, 2011). Towards this end, the country is reported to have planted 350 million tree seedlings in a day across the country (UN environment, 2019). In 2009, Ethiopia also planted more than one billion trees (Ellis *et al.,* 2009). In fact, tree planting is a major component of several development activities, including the Managing Environmental Resources to Enable Transitions to more sustainable livelihoods (MERET) Program and the Productive Safety Net Program (PSNP), and the Sustainable Land Management Program (SLMP).

4.2 Household and community responses

4.2.1 Livelihood diversification and migration

Livelihood diversification and migration are commonplace in Ethiopia (Carswell, 1999). Among others, rural households use livelihood diversification and migration to manage climate change risks and land degradation. In the context of Ethiopia's smallholder agriculture, livelihood diversification involves decisions to pursue a mixed crop-livestock farming system, generate income from different income sources including remittances and off-farm wages, and rely on local social relations and kinships in order to make a living. Many empirical studies (e.g. Little *et al.,* 2006; Scoones and Wolmer, 2000) have shown that diversifying livelihood assets and economic activities has helped enhance their resilience and secure their livelihoods in the context of continued climate change and variability. Despite its importance, livelihood diversification has not been easy for poor Ethiopian rural households. For example, Loening *et al.* (2008) report that only 25 percent of the rural households in Amhara, Oromia, SNNPR, and Tigray regions of the country participate in the non-farm enterprise sector.

4.2.2 Community collective action

Collective action is essential for the better planning and implementation of measures, not only to adapt to and mitigate climate change effects, but also to reverse degradation of natural resources such as land, forests, and water. However, previous empirical studies for Ethiopia (e.g. Tesfaye *et al.,* 2012; Benin and Pender, 2006; Gebremedhin *et al.,* 2004) show that not all collective actions are successful in achieving their desired goals. For example, Benin and Pender (2006) show that collective action in community grazing land management in Amhara region of Ethiopia is more effective in communities with better access to markets and larger populations. According to the authors, communities with greater social, economic, and cultural heterogeneity or more affluent members are less likely to take successful collective action. Likewise, Tesfaye *et al.* (2012) report forestry collective actions of communities in Southern Ethiopia were less successful in remote areas and in locations where local people were more dependent on forests for their livelihoods.

4.2.3 Farmer and indigenous innovations

Ethiopia has various farmer and indigenous innovations that have been used for natural resource management. According to a recent report by Jirata *et al*. (2016), these innovations include, but are not limited to, Traditional Conservation Agriculture (e.g in Derashe), Cultural Landscape (e.g., in Konso), Traditional Soil and Water Conservation practices (e.g., in Hararghe Highlands), Small-Scale Traditional Irrigation (e.g. Hararghe), Manure Management (e.g. in Ankober), and Traditional Agroforestry (e.g. in Gedeo, East Shewa, East Wollega, and West Gojjam Zones (Jirata *et al*., 2016)). Despite their widespread existence, the efficiency and effectiveness of farmer and indigenous innovations as a response to climate change and variability remain under-researched in Ethiopia.

4.3 Policy-level responses

Adapting to and mitigating climate change as well as reversing land degradation are priorities of the Government of Ethiopia. In this regard, the following are some of the main policy-level responses undertaken by the Government to promote the dual goals of improving people's livelihoods and promoting sustainable natural resources management in the country.

4.3.1 Facilitating carbon trading

Among others, Ethiopia's CRGE strategy stipulates raising financial resources through facilitating carbon trading. The strategy envisions a climate change-resilient national economy with a zero-net increase in green-house gas emissions in 2025 over its 2010 level (Gonzalo *et al.,* 2017). Carbon trading is seen as an important mechanism to mobilize financial resources for the implementation of the CRGE strategy. To facilitate carbon-trading, the country established a REDD+ National Secretariat (FDRE, 2016). However, payments for emissions reductions remain low in Ethiopia. For example, only one project, namely the Humbo and Sodo community-based Natural Regeneration Project,[14] was operational in 2016 (UNEP, 2016). The payment for carbon-sequestration has been paid out by the World Bank and the Government of Canada (Cross and McGhee, 2015).

4.3.2 Land-use zoning and integrated landscape planning

Ethiopia does not have a national integrated landscape plan and land-use policy (Gebeyehu *et al*., 2017; Gebreselassie et al., 2016). As a consequence, the country experiences unplanned and mostly uncontrolled land-use practices, especially in rural areas. This state of affairs has contributed to the continuing degradation of land and other natural resources in the country (e.g. Gebeyehu *et al*., 2017; Gebreselassie *et al*., 2016). To avert this problem, the Government of Ethiopia now plans to introduce a national land use plan in the country's next Growth and Transformation Plan (2020-2024) (Gebeyehu *et al*., 2017).

4.3.3 Payment for ecosystem services (PES)

A number of benefits to society emerge from ecosystem services like soil and water conservation, provision of reliable water supply and carbon sequestration. There is a high national level of awareness about the benefits of ecosystem services. For example, Ethiopia's Forest Sector Development Program (MEFCC, 2016) considers that PES is a crucial mechanism for promoting sustainable management and use of forest and related natural resources. However, as a recent official government document shows (MEFCC, 2016), many of these ecosystem services from natural resources are either undervalued or have no financial value at all. One of the potential PES that the Government of Ethiopia expects to seize is water-based PES opportunities from its expanding hydro-

[14] See Cross and McGhee (2015) for details about this project.

power sector in the country. This has not been materialized yet because, as MEFCC (2016, p. 73) pointed out, "—there is no institutional awareness among the potential buyers of the services, principally Ethiopian Electric Power Corporation (EEPCO) to streamline PES into the power plant operation business". As described earlier, the main source of PES in Ethiopia has been associated with payments for carbon-sequestration services provided by the Humbo and Sodo Community-based Natural Regeneration Project (Cross and McGhee, 2015).

4.3.4 Providing access to markets and agricultural advisory services

Improving smallholder farmers' access to markets and agricultural information and knowledge is policy priority in Ethiopia (MoARD, 2017; Gebremedhin *et al*., 2006). The country's agricultural extension policy aims to enhance production and productivity of smallholder agriculture. In this regard, the Government is committed to encourage and support economically viable and environmentally sustainable agricultural technologies and practices and has so far heavily invested in building farmer training centres (FTCs) and training agricultural development agents (DAs). As a result, the number of DAs has increased from 2,500 in 1995 (MoFED, 2006) to more than 72,000 in 2017 (Berhane *et al*., 2018), the largest in Africa. The Government plans to establish 18,000 FTCs (i.e. one FTC per local administrative area/Kebele) and had already established about 12,500 FTCs by the end of 2016 (MoANR, 2017). Every rural Kebele in the country is provided with three DAs, each with respective specializations in crops production, livestock production, and natural resources management. In 2017, the Government of Ethiopia in collaboration with the Agricultural Transformation Agency (ATA) launched a new agricultural extension strategy to speed up agricultural transformation in the country (MoANR and ATA, 2014). The main guiding principles of the new agricultural extension strategy are the following: (1) ensuring market-led production systems; (2) developing location-specific and agro-ecology-based interventions; (3) development of competent and skilled human power; (4) specialization and diversification; (5) maximizing the available potential; (6) maximum use of rain-fed and irrigated agriculture; (7) developing participatory extension methods and approaches; (8) gender mainstreaming; (9) natural resource management and environmental mainstreaming; (10) value chain-based extension approach; (11) government-led pluralistic extension service provision; (12) promotion of financial literacy and improved access to finance; and (13) the scaling-up of good practices.

Several authors (e.g. Gebremedhin *et al*., 2006; Berhane *et al*., 2018; Belay and Abebaw, 2004; Abegaz and Wims, 2015) have studied the performance and challenges of Ethiopia's agricultural extension system over the past years. Among others, Abegaz and Wims (2015) show the potential of the agricultural system to influence farmers' behavior on climate change adaption and mitigation. However, several challenges remain that need to be addressed. Research also shows that the impacts of extension vary by location (Hamilton and Hudson, 2017). According to the authors, advisory services on animal husbandry and fertilizers are most effective for drought-affected areas. In contrast, advisory services on marketing, and land management and other agricultural practices are most effective for non-drought areas (Hamilton and Hudson, 2017).

Apart from its agricultural extension system with wide coverage, the Government of Ethiopia has formulated and adopted the Ethiopia Commodity Exchange (ECX) initiative with the aim of linking smallholder farmers to markers and improving their living standard. According to Andersson *et al*. (2016), ECX has reduced market transaction costs and contributed to increased marketing efficiency in the country.

4.3.5 Securing land tenure

Land in Ethiopia is state property and rural households only have user rights. As a consequence, households have had no guarantee on over which period they would operate their land (Mekonnen, 2009; Deininger *et al*., 2011). As a result, land tenure insecurity had been one of the major constraints to farmers' adoption of sustainable land management practices in Ethiopia. To minimize

the problem, the federal Government and its regional states have run a rural land certification program since 2003. Several empirical studies show the program has encouraging initial results on different land investment and livelihood outcomes. For instance, Deininger *et al.* (2011) find that the program has significantly increased land tenure security, investment on land and participation in land rental markets.

4.3.6 Empowering women

Gender inequality is still widespread in Ethiopia. Several empirical studies in the country show that women have less access to and control over resources as compared to men (Bayeh, 2016; Kumar and Quisumbing, 2015; Hallward-Driemeier and Gajigo, 2015). Empowering women is one of the policy priorities of the Government. For example, the 1995 Ethiopia constitution and the revised Family Code in 2000 (FDRE, 2000) provide women and men equal rights in all legal, economic, social, and political spheres. Recent empirical studies (e.g. Hallward-Driemeier and Gajigo, 2015) report that the revised Family Code has increased women's empowerment as measured by their labour market participation. Another recent policy measure of crucial importance to women's empowerment in Ethiopia is the land certification program, in place since 2003. This program assigns equal land access rights to both spouses of a household (i.e., husband and wife), with each plot registered in the names of both husband and wife.

Previous studies on the impacts of the joint land registration/certification program on women's empowerment provide mixed results, however. For example, Melesse *et al.* (2018) report that the joint land certification program has significantly increased certain aspects of the empowerment of women (e.g., participation in household's decisions, participation in community affairs, and freedom to work outside the home) in Amhara region, Ethiopia. However, the program has limited impacts on women's participation in land rights-related activities (Melesse *et al.,* 2018; Quisumbing and Kumar, 2014). In other words, women's land rights continued to lag behind those of men. As such, increasing women's knowledge of their legal land rights is essential to enhancing the adoption of sustainable land management practices in the country (Quisumbing and Kumar, 2014).

5 Evaluation of existing major policies

5.1 The Agricultural Growth Program (AGP I and AGP II)

The AGP is a five-year comprehensive agricultural development program designed with unique features in order to increase agricultural productivity and production in a sustainable manner, to enhance market performance and facilitate value addition in selected and targeted high agricultural potential areas of the country, and to address some of the key constraints to agricultural growth. A focus on value chains is made to ensure significant value addition along the supply chain to boost the incomes of target beneficiaries in a sustainable manner. The main components that make up the AGP are: (1) agricultural production and commercialization; (2) rural infrastructure development; and 3) project management. The first phase of the program was planned to be implemented from 2010 to 2015, corresponding to the GTP I period, but was extended up to 2017. During the GTP-I period, the overall economy grew at the rate of 11 percent per annum, to which AGP has also, as one of the development initiatives, made substantial contributions.

The objective of AGP I was to improve productivity and market access for key crop and livestock products mainly through improved technologies (including demonstration of improved crop, row planting, seed and fertilizer) and livestock (forage and breed) production technologies that give more yield per unit area/animal and infrastructural development, including irrigation, road and market sheds. AGP I covered 2.2 million households living in 2433 kebeles in 96 high potential woredas[15] in the four major regions (Amhara, Oromia, Tigray and SNNP). The total investment of AGP I was about USD 268.8 million, although it was originally designed for USD 150 million with contributions from different donors.[16]

The second phase of the program, AGP II (2015 – 2020), was designed on the basis of the lessons drawn from AGP-I and aims to contribute to GTP II objectives by expanding its implementation areas beyond the beneficiaries of AGP I to 157 woredas, improving implementation and maximizing the overall impact of the program. The overall objective of AGP-II is to increase agricultural productivity and commercialization of smallholder farmers targeted by the program and also to contribute to dietary diversity and consumption. AGP-II operates in high-growth potential districts selected from seven national regional states and one city administration primarily based on agro-ecological conditions and access to markets targeting more than 2.8 million households (20.1 million people). The 96 districts that benefited from AGP-I interventions are also beneficiaries of AGP-II to consolidate past achievements and strengthen capacities built. The estimated budget for AGP II is USD 562 million.

According to the implementation assessment report of the Ministry of Agriculture (2017), AGP I significantly improved the adoption of agricultural technologies, increased per unit yield, and boosted labour productivity and research-extension linkage. Furthermore, it initiated institutional setups for the innovative production and marketing of agricultural products, introduced approaches and interventions that benefited women and youth, and significantly expanded production through establishing irrigation infrastructure and constructed market infrastructure. It also nurtured and demonstrated the Government's own capacity for effective coordination in project cycle management.

The major lessons learnt from the implementation of the AGP include: the importance of value-chain interventions including increasing productivity along with market linkage, capacitating farmer training centres (FTCs) for the demonstration of technologies and the scaling-up of good practices. In

[15] A Woreda is equivalent to a district.

[16] These included USD 150 Million from IDA, USD 50 million from the Global Agriculture and Food Security Program (GAFSP) and USD 50 Million from the Multi-Donor Trust Fund with contributions from the Netherlands, Canada and Spain, and parallel financing from USAID and Italy.

addition, the project showed that success depends on the involvement and coordination of stakeholders. It also provided for technology demonstrations to be followed by scaling, and demonstrated the importance of working capital for improved livestock and promoting suitable natural resource management. AGP I had also faced some challenges, including limited business leadership skills, poor-quality infrastructure, limited capacities of research institutes, unavailability of improved technologies, and so on (MoA, 2018).

5.2 The Productive Safety Net Programme (PSNP)

Ethiopia had been forced to launch international emergency appeals for assistance nearly every year as chronic poverty and chronic food insecurity are widespread. However, the emergency assistance did not distinguish between different types of food insecurity issues, although ensuring food security has always been among the highest development priorities. Hence, an alternative program called the Productive Safety Net Program (PSNP) was initiated to support the needs of chronically food insecure households, as well as to develop long-term solutions to the problem of food insecurity.

The Productive Safety Net Program (PSNP) is a large-scale social protection intervention developed jointly by the Government and its development partners aimed at improving households' food security, livelihoods and nutrition and stabilizing assets for the most vulnerable households. It was initiated in 2005 with the objective of protecting and creating household assets for chronically food insecure households in rural Ethiopia and is now in its fourth phase (FDRE, 2017; Drechsler and Soer, 2016). The program was seen as a way to confront disasters before they occurred by reducing household vulnerability and helping to prepare for shocks (Jeremy and David, 2014). The program is regarded as the largest social protection program in sub-Saharan Africa, after South Africa, in terms of number of beneficiaries, geographic coverage and budget. The overall responsibility for the implementation of PSNP rests in the hands of the Ministry of Agriculture at the federal, regional and local levels.

Phase 1 of the program was implemented from January 2005 to December 2006, targeting about 4.84 million beneficiaries. Phase 2 was implemented from January 2006 to December 2009, benefiting over 7.57 million beneficiaries, and Phase 3 ran from January 2010 to December 2014, providing support to over 8.3 million beneficiaries. Currently, phase four of the program is being implemented for the period from 2015 to 2020.

The program prescribes a combination of productive safety-net transfers through labour-intensive food- for- work (FFW) and cash transfers as well as unconditional transfers to the elderly, disabled, or orphans who are incapable of working. More specifically, the activities comprise of (1) safety-net grants which include: labour-intensive public works that provide transfers to able-bodied households; (2) direct support that provides transfers to labour-poor households; (3) drought risk financing to provide timely resources for transitory food insecurity in response to shocks; (4) improving capacity to administer risk finance facility; (5) strengthening the delivery of demand-driven and market-oriented advice; and (6) improving the efficiency and effectiveness of financial service delivery to food-insecure households.

Most of the PSNP beneficiaries are required to contribute to public work programs, which is the productive element of the program. Payments can be both cash transfers and/or food distributions. Households eligible for direct unconditional transfers are those who, in addition to being chronically food insecure, have no labour and no other source of support. The PSNP is also gender-sensitive. For instance, women have only 50 percent of the public workload of men due to their domestic childcare and other household duties and they are fully exempt from public work during pregnancy and breastfeeding. Lessons learned from the rural PSNP have been used to design and implement the Urban Productive Safety Net Program (UPSNP), which tries to address chronic food insecurity in urban areas.

PSNP certainly mobilized a lot of resources and provided cash and/or food transfers to millions of households between 2005 and 2015. The total budget for the third phase of the project was over USD 2.62 billion for the 5-year program, of which 14 percent was the government's share. The total budget for PSNP4 is USD 3.2 billion for five years (2015-2020), which will be drawn from several bilateral and multilateral development partners including the USAID and the World Bank. The urban PSNP, on the other hand, was allocated a budget of US$450 million for five years.

The achievements of the PSNP have been substantial. It has significantly improved food security of millions of Ethiopians. Various community infrastructures such as roads, irrigation facilities, etc., have been constructed to contribute to local development and environmental rehabilitation (Gush Berhane *et al*., 2013; Gilligan, Hoddinott, and Taffesse, 2009; Berhane *et al.,* 2012).

The PSNP has also had some limitations. These include timely delivery of transfers, effective linkages to livelihood opportunities, ensuring quality of public works, and institutional coordination. It has also not been able to meet the widely expected graduation of households at the expected scale due to the weaknesses of the livelihood component of the project, which was designed to enable selected households to secure wage employment or to be self-employed by starting small businesses through providing business start-up or job search grants depending on the pathway chosen (Berhane *et al.,* 2014; USAID, 2015; Guush *et al*., 2018). The targeted households could not generate enough assets to graduate from the program for a number of reasons, including inadequacy of support, a sustained dependency mindset and unexpected natural anomalies (Berhane *et al.,* 2013).

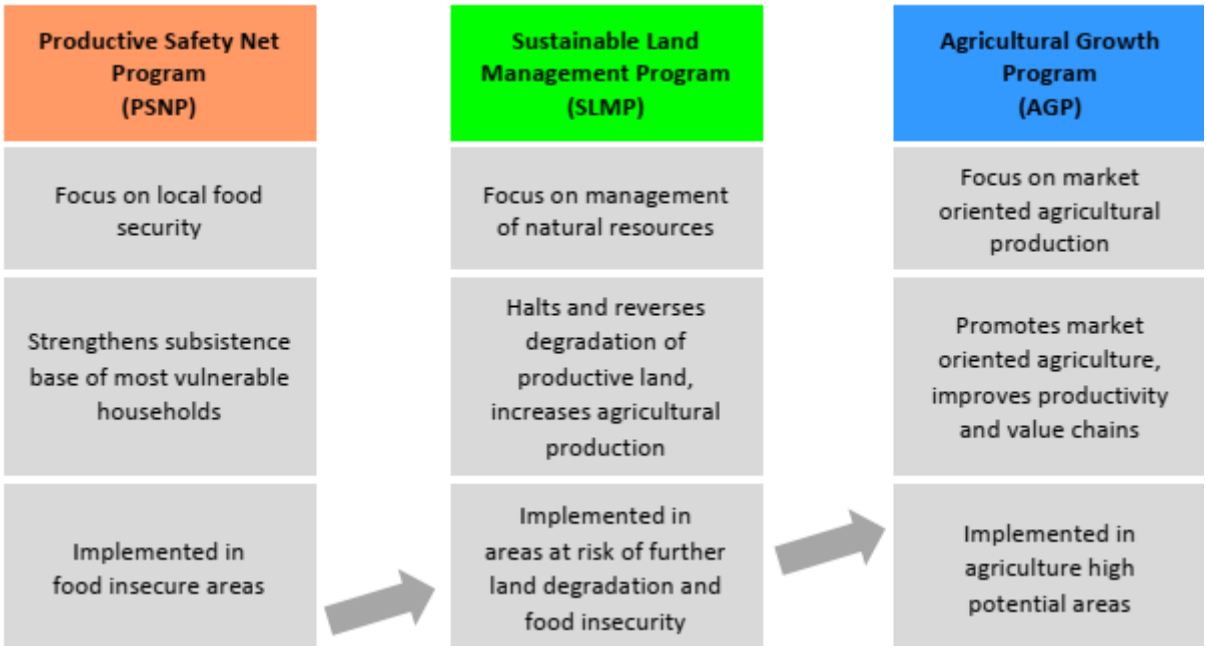
Some of the key lessons from the PSNP include the importance of appropriate targeting, designing adequate packages of support and the need for closely following the implementation of the program to enhance food security. The project was also inclusive as it benefited different groups such as women, youth and adults who are unable to work. The integration of conservation of natural resources, the importance of community infrastructure, and participatory selection processes are additional lessons.

5.3 The Sustainable Land Management Program (SLM)

It is clear that the enhanced productivity of the agricultural sector rests on sustainable management and use of the land resources. As shown in the previous sections, land degradation is of particular importance for Ethiopia because the Ethiopian environment is mountainous and thus very easy to degrade. Sustainable land management is a comprehensive approach to address water scarcity and to restore soil fertility, organic matter and biodiversity. Fostering sustainable land management needs an appropriate policy framework that takes into account both the interests of the present and future generations in a dynamic and evolving environment. Recognizing the extent of land degradation and its impact on rural food security and the livelihoods of rural people, the Ethiopian Government initiated a massive program of soil conservation and rehabilitation program called the Sustainable Land Management Program (SLMP).

The SLMP is a donor-assisted integrated watershed management long term program that was initiated in 2008 and is one of the three flagship programs in the agricultural and rural development sector. It is strategically positioned between the Agricultural Growth Program (AGP) and the Productive Safety Net Program (PSNP) (see Figure 7). The program was initiated to make agriculture more productive and sustainable and encourage natural resource conservation, thereby promoting growth and poverty reduction in rural areas by addressing the environmental problems facing the country.

Figure 7: Agricultural and Rural Development Flagship programs



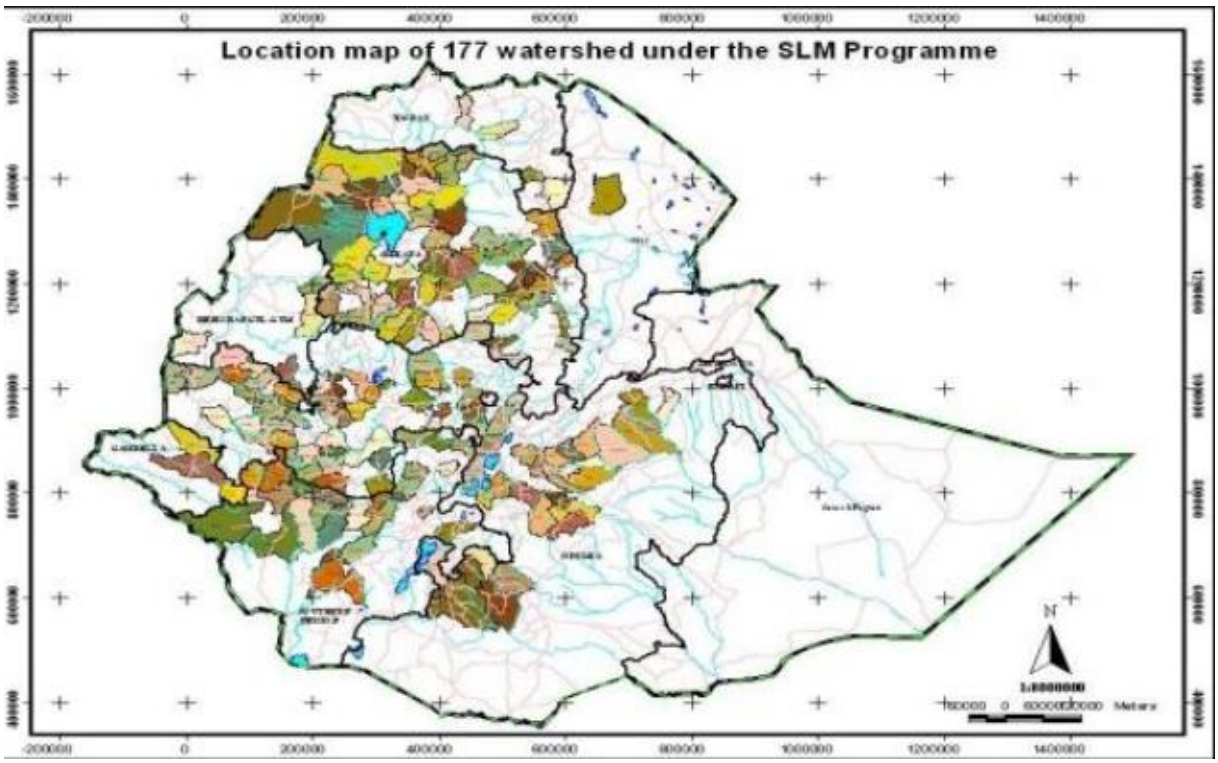
Source: GIZ (2018).

The Program aims to combat land degradation, improve agricultural productivity of smallholder farmers, restore soil fertility, facilitate tenure security, restore ecosystem functions, and enhance participatory forest management and bio-diversity conservation measures. The SLM project provides smallholder farmers with support to adopt sustainable land management practices on a wider scale and to reverse land degradation in agricultural landscapes to increase agricultural productivity and income growth. It is managed and coordinated by the Natural Resources Directorate under the Ministry of Agriculture.

The SLMP has five components: policy advice, watershed management, knowledge management, land administration and utilization and project management. The project is firmly aligned with the GTP and the CRGE, both of which are looking to an agriculture-driven and sustainable green economic growth with lower carbon footprint and resilience to climate change. Special focus is made to designated locations for hydro-dam construction, such as the Abay, Omo, Gibe and Melka-Wakena rivers. Another focus area in this project includes technology transfers that enhance income-generating activities such as the production of fruits and vegetables.

The SLM program has now entered its third phase. The first phase of the program (SLM I-2009- 2013) targeted 176 critical watersheds in 182 woredas in six regions (see Figure 8). The second phase SLMP-II was a five-year program (2013-2018) that covered 135 woredas in six regions. The third phase is the Resilient Landscapes and Livelihoods Project (RLLP), which aims to expand and consolidate the lessons and successes of SLMP-II. Its objectives are to improve climate resilience, land productivity and carbon storage, and to increase access to diversified livelihood activities in the selected rural watersheds in the six regions. The project will address a total of 628,436 households (529,461 male-headed households and 98,975 female-headed) with a total population of 3.2 million, of which 1.4 million are female, over a five-year period (2018-2022).

Figure 8: SLMP program locations



Source: Mahoo *et al*. (2013).

The budget for SLMP I was USD 37.8 million, while for SLMP II the budget was USD 107 million. The RLLP has a planned budget of USD 100 million with contributions from the World Bank IDA, GAFS, the Government of Norway and the Government of Ethiopia.

During the first two phases of the SLM project, a wide variety of activities relevant to sustainable land management, such as landscape and watershed management, rural land administration and land use, institutional strengthening, etc., were undertaken related to the different components. Evaluation reports confirmed that SLMP I and II made remarkable progress in rehabilitation, protection and economic use of the targeted degraded areas and in improving their soil, water and vegetation. Large areas have been physically reclaimed and rehabilitated, even though the challenge remains due to continuing human activity and the depth of the problems, which extend far beyond the actions taken (Diriba, 2018). The project was successful in improving soil fertility in degraded highlands. It encouraged wide community engagement and built up the capacity of actors in land certification, which further contributed to improving land tenure security. Upon completion of SLMP I, a total of 209,926 ha or 99 percent of the target had been effectively covered and rehabilitated by project interventions.

The projects have enhanced agricultural productivity, both crop and livestock, by providing water for irrigation, pasture for livestock and introducing sustainable agricultural practices in water management, agro-forestry, and conservation agriculture. They have also significantly contributed towards the improvement of income, asset creation, food and nutrition security and building livelihood resilience against drought and other shocks.

In spite of these achievements, the SLMP suffered from inexperience in major procurement and project management challenges in earlier years, as well as from high staff turnover, a lack of facilities including internet access and vehicles, difficulties over land ownership, competing claims over communal resources and climatic effects.

The key lessons gained included the importance of inclusiveness of action for different social and income groups. Starting from the design, a participatory, innovative, transformative and multi-sectoral landscape approach has been followed. It linked SLM with livelihood activities, participatory planning and use of its own internal capacity for planning and managing big projects and building local institutions. It provided paid labour work for landless women and youth and unconditional transfers for people with social, health and other problems. It achieved and sustained management of results and the alignment of externally supported projects with already-existing government programs.

5.4 Climate Resilient Green Economy Strategy

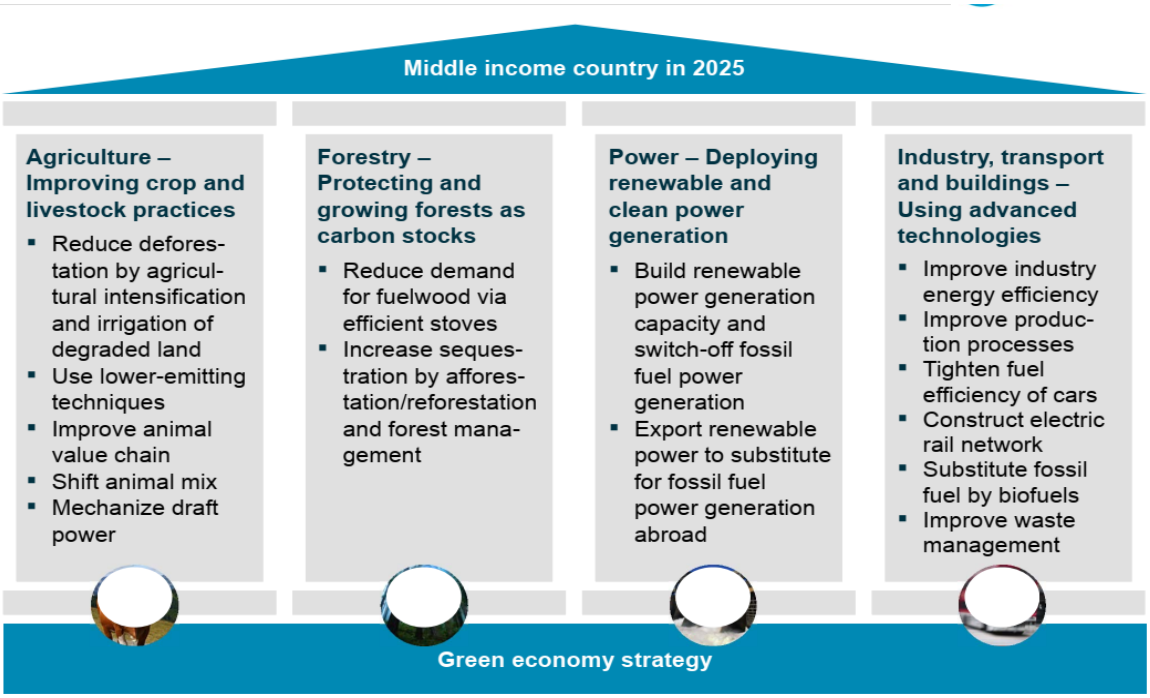
Ethiopia is facing the impact of climate change, which is significantly affecting agriculture and other economic sectors. Climate change is among the main contributors to the food security challenges Ethiopia faces and will continue to be a challenge in the future. As the evidence presented in section three clearly shows, climate change will have significant impacts on the Ethiopian economy. Agriculture, pastoralism and agro-pastoralism, which are the traditional livelihood systems for millions of Ethiopians, are highly sensitive to climate change because of their close links to the natural environment. A recent study on the risks of agriculture in Ethiopia identified drought, crop pests and livestock diseases as among the top five top priority risks related to climate change (PARM, 2016). Indeed, non-climate-related factors such as excessive exploitation of natural resources have also contributed to the stress on the ecosystems on which these livelihoods rely, but climate change exacerbates this stress (USAID, 2015).

This situation has forced Ethiopia to seek for and adopt climate-smart agriculture and livelihood diversification options (USAID, 2015; PARM, 2016). Accordingly, in response to the threat of climate change, the GTPs have underscored the need to mitigate climate change impact through research and adopting climate resilient and climate smart agriculture (NPC, 2016; Demise *et al.,* 2016). To mitigate the impact of climate change, the Ethiopian Government launched the Climate Resilient Green Economy (CRGE) Strategy in 2011, the first of its kind in Africa, and integrated it into GTP II (2015-2020).

The CRGE strategy aims to transform Ethiopia to a middle-income country by adopting a climate-resilient growth path and by taking measures to reduce greenhouse-gas emissions. The strategy attempts to integrate economic development efforts such as GDP growth rates, infrastructural development, poverty reduction, job creation, and social inclusion, with environmental performance. The planned environmental actions that would accompany the economic development efforts include improving the resilience to climate shocks, mitigation of GHG emissions, reducing biodiversity loss and ensuring access to clean water and energy. This implies that the economic development objectives are addressed simultaneously with environmental and social objectives.

The CRGE Strategy follows a sectoral approach and bases its green economy plan on four pillars: improving crop and livestock production practices; protecting and re-establishing forests for their economic and ecosystem services; expanding renewable power generation; and leapfrogging to modern and energy-efficient technologies in the transport and industrial sectors, and buildings (see Figure 9).

Figure 9: The four pillars of the CGRE



Source: FDRE (2011).

The Environment and Climate Change Commission is responsible for overseeing and coordinating the implementation of the CRGE Strategy. Each economic sector is also expected to cascade and complement the CRGE Strategy's targets and measures in their respective domains, so that Ethiopia's national development and poverty reduction efforts are aligned with the climate resilience goals. The Ethiopian Government had already developed and started to implement a National Adaptation Plan (NAP) starting in 2019, in an effort to bring about transformational change in the country's capacity to address the impacts of climate change (FDRE, 2019).

Implementing the green economy requires USD 125 Billion over the next 20 years (FDRE, 2011). A national financial mechanism, the CRGE Facility, has been established to mobilize, access, sequence, and blend domestic and international finance from public and private sources to support institutional building and implementation of the strategy (LSE, 2017).

Some of the important lessons drawn from the Ethiopian CRGE strategy include the need for grounding the analysis and policy insight in the current context (existing government policies, plans and vision), and engaging all the key stakeholders early-on and continuously over the project life cycle to create ownership, and the need to highlight the benefits beyond just mitigating greenhouse-gas emissions.

6 Conclusion and policy implications

Our review of the literature provides evidence that climate change and land degradation present serious environmental and development challenges to many sectors of the Ethiopian economy. Local populations and the Ethiopian Government have responded to the challenge at varying scales at all levels. Historically, Ethiopian small farmers and pastoralists are known to use various risk management strategies, including livelihood diversification and migration and crop diversification.

The Government has adopted and formulated various sector-specific and economy-wide policies, and programs to deal with the challenges of climate change and land degradation at all levels. Some of the major macro-responses include the recently adopted Agricultural Growth Program (AGP), the Productive Safety Nets Program (PSNP), Sustainable Land Management Program (SLM), and Climate-Resilient Green Economy (CRGE) Strategy.

Apart from these programs and initiatives, the Government has developed new strategies and guidelines to deal with climate change and growing land degradation in the country. These include national strategies for the Agricultural Extension System, and for small-scale irrigation and drainage. Among others, both the sector-specific and economy-wide programs and strategies encourage and support the adoption of climate-smart agricultural technologies such as irrigation, rainwater-harvesting, agro-forestry, drought-tolerant crops and crop varieties and enhance sustainable management and the use of land and other natural resources.

Despite these efforts, challenges remain. These challenges include, but are not limited to: (1) heavy dependence on rain-fed agriculture and widespread exposure to drought; (2) high dependence on biomass energy sources including firewood and charcoal; (3) rapid expansion of invasive species (e.g. *Prosopis juliflora*), especially in the lowlands, where livestock production is the main source of livelihood; and (4) lack of a national land-use policy.

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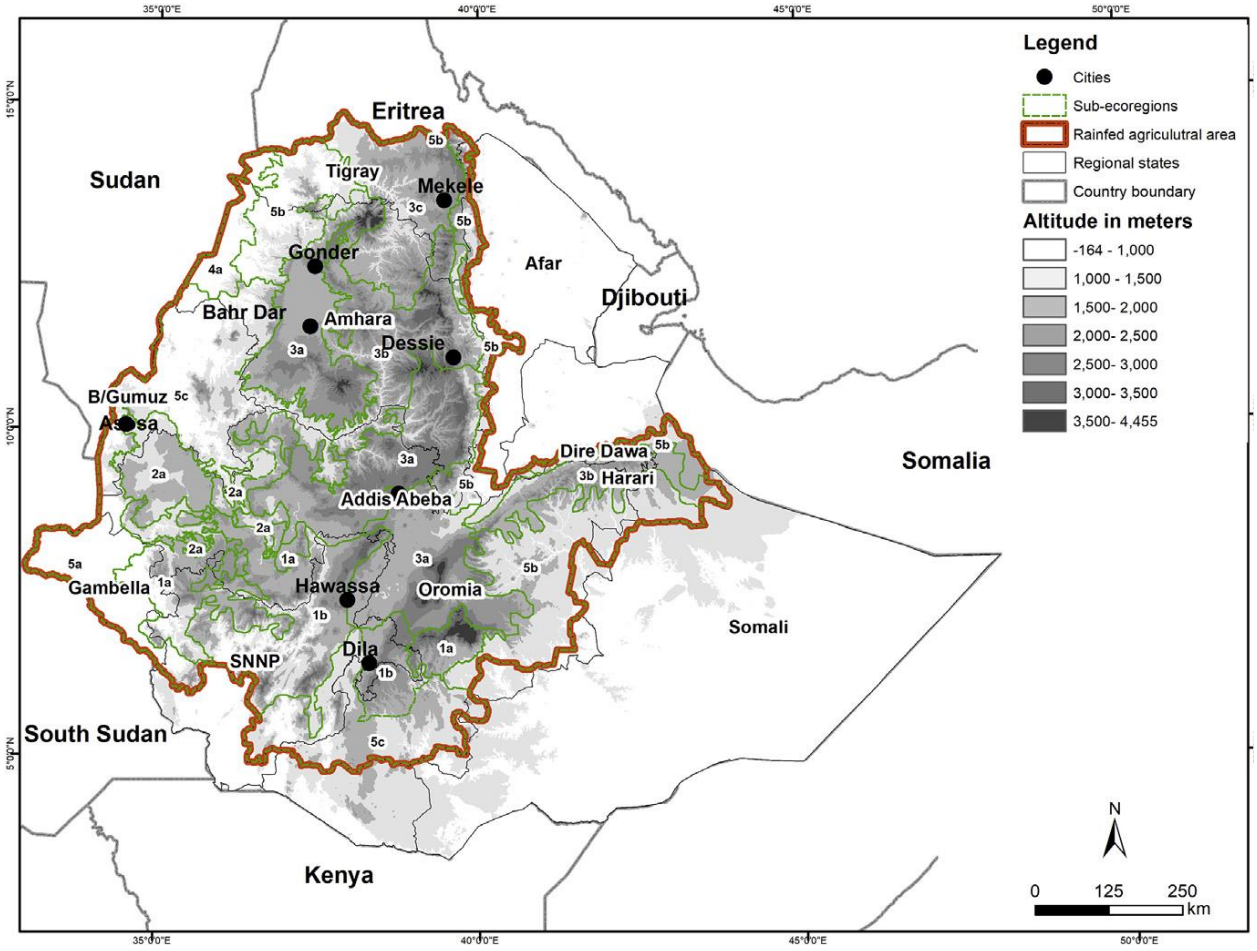
Annex

Figure A1: Boundaries showing Ethiopia's RAA and eco-regions



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