



## ETHIOPIAN PANEL ON CLIMATE CHANGE

### FIRST ASSESSMENT REPORT

WORKING GROUP II- CLIMATE CHANGE IMPACT,  
VULNERABILITY, ADAPTATION AND MITIGATION

II

# AGRICULTURE AND FOOD SECURITY

ETHIOPIAN ACADEMY OF SCIENCES



Ethiopian  
Academy  
of Sciences

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Ethiopian Institute of Agricultural  
Research  
Research Center for  
Climate Change and  
Adaptation



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#### **About the Ethiopian Academy of Sciences**

The Ethiopian Academy of Sciences (EAS) was launched in April 2010 and recognized by an act of parliament (Proclamation No. 783/2013) as an independent institution mandated to provide, inter alia, evidence-based policy advice to the Government of Ethiopia and other stakeholders. Its major activities include undertaking consensus studies, conducting convening activities such as public lectures, conferences, workshops and symposia on issues of national priority; as well as promoting science, technology and innovation.

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**AGRICULTURE AND FOOD SECURITY  
SUB-WORKING GROUP**

**MIXED CROP-LIVESTOCK SYSTEM**

## Introduction

### 1.1. Attributes of Ethiopian Agriculture

The Ethiopian economy is largely dependent on agriculture which is largely a “low-input and low-output” subsistence production system. Despite the over 3,000 years of application by the overwhelming majority of the country’s population, agriculture has changed only marginally from its original form. The overwhelming majority of the country’s farmers and herders still rely on age-old technologies and agricultural management practices that invariably result in low productivity and production. This state of affairs has resulted in consistent agricultural production failures to meet the food and feed needs of a significant proportion of the human and animal population of the country. This is in direct contrast to what is expected, considering the country’s endowment of abundant agricultural and natural resource potential and marketing opportunities both within and outside the country. Needless to say, there are serious bottlenecks/challenges in exploiting the abundant natural resources related to agriculture. A brief summary of the potentials and challenges in relation to Ethiopian agriculture will help in assessing the future prospects of agricultural development in the face of impending climate variability (CV) and climate change (CC).

#### 1.1.1. Natural agricultural resource base potentials

Ethiopia’s abundant agricultural and natural resource base can be described under the following categories:

**Land resources:** the total area of the country is said to be about 1.17 million km<sup>2</sup> or 117 million hectares, over 60% of which can be used for some form of agricultural production activities. However, according to CSA’s annual survey of land under crops by small-scale farmers over many years show that it has been in the range of 13-14 million hectares in any given year (FDRE/ CSA 2013/14-a). The overwhelming proportion (95 %) of the cropped area is under small-scale rain-fed farming that accounts for 95 % of the national annual crop production.

**Animal resources:** Ethiopia is said to have the largest number of domestic animals in Africa, estimated at 55.03 million cattle, 27.4 million sheep and 28.2 million goats in addition to a large number of poultry, camels and equines (pack animals) (FDRE/CSA 2013/14 b). However, almost all of these animals are of indigenous origin; exotic species representing a very insignificant proportion of the national herd.

**Bio-diversity (Genetic) resources:** - Ethiopia is recognized as one of the eight Vavilovian centers of origin or genetic diversity for many economically important crops (Huffnagel, 1961). Even some of the non-indigenous crops and livestock introduced into the country so long ago that they have adapted to the local environmental conditions so well that they act as indigenous species. The greatest majority of farmers and herders rely on these species of crops and livestock in agricultural production activities.

**Water resources:** - Ethiopia is considered as the “water tower” of Africa as many rivers flow out of the country because of its high altitude that forces such outflows to the surrounding countries. In addition to the relatively high rainfall, particularly in the western part, the country is endowed with a significant amount of water resources from lakes and rivers as well as from under-ground sources. It is estimated that the country’s irrigation potential is close to 5.4 million hectares, comprising of over 3.7 million hectares from surface water sources (rivers and lakes), over 1.16 million hectares from ground water sources and about 0.5 million hectares from rain water harvesting (Sileshi Bekele Awulachew, 2010) .

**Agro-ecology resources:** -the country’s location close to the Equator and its diverse range in altitude entail the existence of a wide range of agro-ecological conditions that favor the production of a wide range of crops and livestock. The mid- and high altitude agro-ecologies favor the production of dominant crop types that include cereals (mainly wheat, barley, tef, maize, sorghum and finger millet), food legumes (mainly faba beans, field peas, chick peas and lentils), oil seeds (mainly noug, linseed, rapeseed, groundnut and sesame), and root and tuber crops (such as Irish potato, sweet potato, enset, and several others). There are agro-ecologies suitable for several important cash crops such as coffee, cotton, sugar cane, various types of fruits and vegetables grown for export and/or domestic uses. The low altitude areas





are mainly suited to pastoral and agro-pastoral activities based on animal production except where irrigation systems are developed for crop production activities.


### 1.1.2. Challenges

The exploitation of the above-mentioned natural resources is constrained by a myriad of challenges that need to be overcome through mitigation or adaptation of various man-made and natural shocks. These include, among others, the following.

**Climatic:** - Since Ethiopia's agriculture is overwhelmingly rainfall-dependent, it suffers greatly from the risks associated with high rainfall variability. Long-term records indicate that there have been severe and repeated rainfall failures resulting in severe food/feed insecurity, including famines, on the Ethiopian population due to significant loss of crops and livestock. The frequency and severity of these natural shocks has increased in recent years (Mahoo et al., 2013). Needless to say, such shocks result not only in hardships to human and animal populations but also thwart seriously economic development efforts.

It should be noted that pastoralists and agro-pastoralists almost solely depend on rain-fed agriculture and are more exposed to vagaries of climate change and variability than the highlands. Hence, they are food and feed insecure. During droughts and severe feed and food shortages, pastoralists and agro-pastoralists rely mostly on food aid to mitigate complete disaster.


**Technological:** - the Ethiopian farming and herding communities have been, and still are, largely dependent on traditional crop "land races", indigenous animal stocks as well as poor management practices and poorly organized value chains, particularly marketing systems. This state of affairs results not only in low crop and animal productivity but also in inadequate incentives to encourage greater production and productivity. Although "modern" agricultural education, research and extension have been introduced to the country since the mid-1930s (during the Italian occupation) (Huffnagel, 1961), the generation, transfer and adoption of improved agricultural technologies and practices is still far less than required to meet the production needs of food, feed and industrial raw material of the country. Despite the best efforts of the national agricultural research, extension and marketing institutions,



adoption of improved crop varieties, modern agricultural inputs (seeds, fertilizers, crop protection chemicals, farm machines and implements, etc.) and enhanced value chain systems have yet to make significant inroads into the agricultural communities, although there have been some progress made in the last few decades.

**Socio-cultural:-** it can be said that the overwhelming majority of the Ethiopian agricultural communities, be they sedentary or nomadic, are highly traditional and prefer to live by traditional values and norms considered appropriate to their respective communities. This is further aggravated by the high level of poverty and food insecurity leading to risk aversion by way of being reluctant to adopt new technologies and new ways of doing things. These sets of traditional socio-cultural attitudes make the introduction and adoption of improved agricultural practices that have the potential for adaptation and/or mitigation against natural shocks very difficult and a long-term process. As a result, many decades of effort to promote the adoption of improved crop varieties, animal breeds and agricultural management practices have failed to make significant changes in the Ethiopian agricultural production system. Thus, farmers'/herders' responses to natural shocks remain largely traditional and poorly developed to withstand shocks due to CV and, indeed, CC.

Another dimension to socio-cultural issues relates to gender streamlining in agricultural activities as well as in other economic development sectors. It is known that female members of the agricultural communities play a very significant role in many agricultural activities, besides their role as home makers (Lemlem Arega et al., 2011). Many of the technologies generated through agricultural research do not adequately focus on the special requirements of women and girls. It also needs to be added that both the national agricultural extension system as well as the financial institutions also fail to properly address the need to develop mechanisms to minimize, if not eliminate, gender-bias in extending their services. Therefore, the huge potential that can be developed by streamlining gender-issues has been lost over the years. However, there are current indications that may improve the situation, even at speeds lower than desired.



**Policies:** - the various governments that have been in power over the last decades have developed and implemented a large number of policies and strategies to enhance agricultural production and productivity. These included policies related to land and water development as well as the generation and dissemination of technologies related to crops, livestock, agricultural inputs and agricultural mechanizations. Despite these, however, the issue of climate variability, much less climate change, has never been central to these policy concerns. Although some attention seems to have been given to these concerns in recent years, the level of policy focus on issues related to land and water management still lags behind. This is best exemplified by the inadequate attention given to ways and means of improving “land use and land management” which are crucial for minimizing, if not eliminating, land degradation and soil fertility depletion, particularly in the high potential mid- and high-altitude areas of the country that account for the major portion of the crops and livestock produced in the country. Although a new legislation (FDRE Rural Land Administration and Use Proclamation no. 456/2005) has been issued close to ten years ago, there has been limited effort to enforce its tenets. However, the recent mass mobilization on soil and water conservation and land rehabilitation in some regional states is encouraging and it has to be supported by both expert knowledge and region-specific policies and strategies to make it successful and sustainable.

**Institutions:** - one glaring gap in relation to climate variability and climate change has been, and still is, failure to establish a national institution with the necessary legal power and resources to deal with the climate issues at national level. Although the current Government of Ethiopia (GoE) has recently formulated a major policy document (CRGE, 2011) that sets out action plans to deal with climate issues, responsibilities are diffused across many public organizations (i.e., MoFED, MoFE and NMO) which make effective handling of the issue difficult. Recently, the Ethiopian Academy of Sciences (EAS) is also playing an active role in setting up EPCC to deal with the same issue. This requires rethinking, and therefore, calls for assigning a lead institution to deal with the subject on its own in addition to coordinating the activities of other stakeholders.



### 1.1.3. Land use and land management


#### 1.1.3.1. Agricultural production systems

As indicated above, Ethiopia's location close to the Equator and its altitudinal diversity gives rise to varied agro-ecologies for the existence of diverse agricultural production systems. In general, these production systems fall into two broad categories:-1) mixed crop-livestock production system in highland and mid-altitude areas and 2) pastoral and agro-pastoral production system based on livestock production in lowland areas. It should, however, be noted that the former system can be subdivided into two sub-systems, i.e. one based on cereals in high- and mid-altitude areas and the other based on root/tuber and perennial crops in mid-altitude moist and sub-moist agro-ecologies. The mixed crop-livestock production system dominates in terms of population density although it occupies only a little over a third of the surface area of the country, with the rest being under pastoral/agro-pastoral production system.

The impact of climate change on crop production would be mainly through change in temperature, rainfall, which collectively influence the length of growing period, time of critical growth rate, increased evapo-transpiration and hence seriously reduced and in some cases causes complete crop failure (Mahoo et al., 2013). A range of climate change scenarios and models suggest that many parts of Ethiopia are likely to experience a decrease in the length of growing period, and in some areas, the decrease may be severe. The largest losses and gains are predicted for arid and semi-arid areas which have too few growing days for crop production but remain important for pastoralists.

Although Ethiopia is endowed with a substantial number of perennial rivers as well as lakes, the fishery industry is poorly developed to the extent that few actually practice it as a main livelihood system. The same can be said of apiary as a livelihood system despite the large number of bee colonies thought to exist in both the mid- altitude and highland areas where natural forests are still to be found. Although a low proportion of the Ethiopian population subsists on forest and non-forest products in forest and forest-margin areas, it is difficult to categorize this form of agricultural production as sustainable livelihood system.





### **1.1.3.2. Agricultural production and productivity**

Because of the myriad challenges faced, the performance of the Ethiopian agricultural system is well below its expected potential as clearly demonstrated by theoretical and empirical evidences available. Research data show that yields from major field crops could be raised by a factor of 1.5-2.0 times by applying improved agricultural technologies such improved seeds, chemical fertilizers, crop protection chemicals, and irrigation in addition to well-developed cultural/management practices (FDRE/MOFED, 2013).

The same can be said in relation to livestock where data from research centers, for example on dairy cattle show that the production of milk from well managed exotic breeds or their crossbreds with local breeds could be raised significantly by applying improved production systems. For example a comparative study on milk production under small holder and commercial dairy farmers using indigenous and improved (crossbreds) breeds in selected areas of the country show that milk production could be increased from 1-5-2.5 l/day from indigenous breeds to 10-15 l/day from improved breeds. It should also be noted that lactation period of improved breeds is significantly longer in crossbreds compared to local breeds (Tegegne, et al. 2013). Needless to say, the development and application of improved agricultural technologies and management systems could be a major tool to address increased production and productivity through improved technologies and, hence, better potential for adaptations to climate change.

### **1.1.4. Climate extremes and impacts of climate change**

#### **1.1.4.1. Past occurrence of climate extremes and their impact**

Among the many challenges constraining Ethiopian agriculture, none is more severe than that caused by its overwhelming dependence on the vagaries of weather and climate. In the last 50 years, the annual average minimum temperature over the country has been increasing by about 0.2oC every decade. Erratic rainfall and excessive evapotranspiration due to extended dry season have been causing drastic crop yield reductions, or crop failures and decrease herbage biomass yield and carrying capacity of grazing lands. Reports indicate that there have been major droughts in Ethiopia over


the past centuries, 15 of which, in fact, occurred in the last 50 years or so (Mahoo et al., 2013). It would be noted that droughts leading to major losses or suffering in human as well as loss in livestock due to shortage of water and grazing lands. This is severely aggravated when rain failures occur repeatedly (i.e., year after year) both in the short (Belg) and main (Meher) rainy seasons. Drought causes the loss of thousands of animals on which the economy of pastoralists heavily depends. Consequently, food shortage and associated health problems, climate induced disruption of agricultural systems, migration of people to urban areas, flooding and siltation of lakes and watercourses have become common scenarios.

Events like flooding, hail storm and landslides as well as the periodic occurrence of pests (including insects, migratory birds and rodents) and diseases of various types also increase the vulnerability of the agricultural community as well as the national economy, but there are no consistent and comprehensive data and information that can give long-term occurrences as well as future trends. All of these natural factors occur at some point in the agricultural calendar and they can be neither predictable nor easily amenable to prevention measures as might be expected.

The impact of climate change on crop production would be mainly through change in temperature, rainfall, length of growing period, time of critical growth rate, increased evapotranspiration and hence productivity would be seriously reduced and in some cases causes complete crop failure (Beltagy and Madkur 2012, Howden 2007). A range of climate change scenarios and models suggest that many parts of Ethiopia are likely to experience a decrease in the length of growing period, and in some areas, the decrease may be severe (Paul et al., 2013). The largest losses and gains are predicted for arid and semi-arid areas which have too few growing days for crop production but remain important for pastoralists. This impact of climate change is further aggravated by rapid population growth of Ethiopia, projected to reach close to 200 million by 2050.

#### **1.1.4.2. Projected climate change**

There is a large body of literature clearly indicating that there are major challenges to be faced in relation to climate change both globally and in



Ethiopia. Records indicate that there has been a rise in temperature over the past decades and is projected to rise further over the coming decades both globally and nationally. The status of annual precipitation, another main climate change factor, is somewhat mixed. Both factors affect agricultural production and productivity in addition to their serious impact on human health and welfare.

### **1.1.5. Food security and climate variability and change**

#### **1.1.5.1. Definition of food security**

Various development practitioners have defined “food security” in various ways. However, the simplest way of defining it is: “Food security exists when people have sustainable physical and economic access to enough, safe, nutritious, and socially acceptable food for an active, healthy and productive life”.

The above definition connotes various elements that condition food security. These include food availability through domestic production or imports and economic capacity to access food, which in itself must be adequate in terms of quantity and quality to provide enough calories, proteins and minerals adequate for sustained health and productive performance. This connotation, especially in relation to production, also implies conditions such as rainfall and temperatures which are necessary for agricultural production. Thus, climate variability or change has a direct effect on food security.

#### **1.1.5.2. Affected population**

Although food insecurity mainly caused by rain deficit or total failure occurs in almost all regional states of the country, it is most frequent and severe in the dry lowlands and, to a limited extent, in the sub-moist mid-altitude areas. The estimated number of people affected by food shortages in Ethiopia varies from year to year and from region to region. Reports indicate that the Ethiopian droughts of 1974 and 1984 were among the most severe events affecting over 8.3 million people (MOA, 2010). It should be noted that the number of people needing food assistance can be categorized into two broad groups, i.e., those categorized as chronically food insecure and those categorized as transitory food insecure. This means that the former category



of people are permanently in a state of food insecurity under the prevailing environmental and socio-economic conditions and can be corrected if and when these constraining conditions are improved. Those under the second category are vulnerable when environmental and socio-economic shocks are beyond their means. Various estimates indicate that chronic food insecurity affects between 5-6 million people in the country on the average on annual basis while the remaining are classified under the second category. At present, more than 50% of the chronic drought-affected population in the country is from the pastoral areas. In general, in the arid and semi-arid agro-ecologies, the inadequate and erratic rainfall makes water the most important limiting factor to both plants and animals


### **1.1.5.3. Measures taken to minimize impacts on affected population**

Various policies, strategies and measures have been put in place over the years to combat food insecurity in the country. While the GoE played an important role in leading the battle against such shocks, various international organizations and non-government organizations as well as private individuals contributed to mitigate the state of affairs. The major programs that have been and still are under implementation to combat food insecurity include the Productive Safety Net Program (PSNP), Household Asset Building Program (HABP), Complementary Community Investment (CCI) project and Voluntary Resettlement Program (VRP) (MOA, 2010).

PSNP was started in 2005 and has completed three phases and is in its fourth stage of implementation. It is implemented in selected high potential woredas of four regions (Amhara, Oromia, Southern Region and Tigray). It focuses mainly in public work activities such as natural resources conservation (forestry, agro-forestry, gully control, etc.), community water point and small-scale irrigation schemes development and construction of rural roads, schools and clinics.

HABP, started in 2005, is complementary to PSNP and aims to support those “graduates” that have reached a status considered adequate for self-sustenance if faced by “mild” shocks. This is done through assisting “graduates” in business plan development and provision of credit to start their own business. The CCI is basically aimed at developing community





infrastructure such irrigation schemes, rural roads, etc through partnership in investment between the government and the community. Finally, VRP is aimed at resettling vulnerable people from degraded areas to more agriculturally favorable areas.

Recent assessment reports indicate that both the PSNP and the HABP are quite successful and have contributed to reducing the number of vulnerable households. Some of the programs, particularly those related to natural resources conservation and infrastructure development, have a noticeable impact in contributing to mitigating the effect of climate variability on crop and livestock production and rehabilitating the natural environment.

#### **1.1.5.4. Trends in food security status**

Reports indicate that the state of food insecurity has been on the decline over the past few years as a result of the above mentioned measures. The success of these programs, particularly PSNP, HABP and CCI, has encouraged the GoE as well as many of its development partners to continue these programs through allocation of additional funds. The main causes for this “success” in reducing food insecurity both at national and household levels include:-

- Political commitment which includes the formulations and implementation of policies and strategies as well as allocation of the required resources to combat the drivers of food insecurity.
- Infrastructure development mainly in the form of water resources development (small-scale irrigation through river damming or diversion and the construction of ponds, etc) for agricultural activities and for use by humans and animals. The construction of rural roads as well as market centers and job creation through public and private enterprises helps in accessing food items.
- Support and assistance by many major donors
- Finally, the generation and dissemination of improved agricultural technologies plays an important role in raising agricultural production and productivity which is a necessary ingredient for increased supply of foods for humans and feeds for livestock. It is well known that the last few decades have witnessed the expansion of agricultural research and development activities in national and international agricultural research centers as well as in higher learning institutions in the country. Capacity building through various means such as training, logistics support, infrastructure development

## **1.1.6. Response of Ethiopia to the challenges of climate change**

### **1.1.6.1. Policies and strategies**

It is important to note that the GoE is aware of the implications of climate change in relation to social and economic development for the country. It has, therefore, formulated a policy and strategy document to combat such threat. This strategy is put forward in the Climate Resilient Green Economy (CRGE) strategy document published in 2011 and consists of two important elements, i.e. strategy for climate resilience (CR) and strategy for green economy (GE) (CRGE, 2011). While the GE part, consisting of some 60 options, has already been identified during the CRGE strategy formulation, the CR part, consisting of some 41 options in the area of agriculture alone has been recently finalized.

### **1.1.6.2. Mitigation**

The GE part is aimed at promoting conditions that reduce the greenhouse gases emissions due to various types of development activities. The focus in this respect concerns 1) improvement of crop and animal production practices, 2) development of forestry and agro-forestry activities, 3) development of electric power generation through renewable energy sources and 4) expanding the use of modern and energy efficient technologies.

### **1.1.6.3. Adaptation**

The CR strategy is aimed at developing strategies that enhance the capacity to withstand the negative effects of climate change through various activities in various sectors of the national economy. It has the following objectives:-1) identify the impact of current weather variability and project future climate change in Ethiopia, 2) identify and cost the options to build climate resilience and 3) develop the steps to finance the implementation of the selected options.

In general, the occurrence of climate change and its impact on Ethiopian agriculture is well understood and efforts are underway to develop and implement adaptation and mitigation measures. But, the level of knowledge and information related to these events is constrained by the unavailability of



empirical data. However, available information is presented in the following chapters of this assessment report as follows:

Chapter two deals with the impacts of climate change on Ethiopian agriculture. This will cover data and information related to crops, livestock, crop-livestock interaction, socio-economics, food security and natural resources.

Chapter three covers issue related to vulnerability in the Ethiopian context. The issues covered under this heading include drivers of climate change and climate vulnerability, exposure and sensitivity of Ethiopian agriculture to these events, vulnerability and adaptive capacity and socio-economic costs associated with these events.

Chapter four focuses on adaptation to climate change dealing with technical areas such as technology, infrastructure, and knowledge/awareness raising and climate information.

Chapter five aims at climate change mitigation in the Ethiopian agriculture. The main focus areas under this heading is related to controlling/minimizing greenhouse gas emissions through various measures including improving agricultural production practices, using renewable sources for energy production and scaling up the use of energy saving/efficient technologies.

Chapter six aims at synthesis of the issues raised and measures recommended for adapting to and mitigating climate change in the Ethiopian agriculture.

The Policy Implications of the whole assessment exercise will be dealt within the final chapter. This will serve as a Way forward in the form of recommendations for appropriate policy actions to be formulated by the relevant authorities to minimize the impacts of climate change.



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## 2. Impacts of climate variability and change on mixed crop-livestock systems in Ethiopia

### 2.1. General

Climate variability and extreme events (drought and heavy rains) are causing significant damage to life, property, natural resources and economy in Ethiopia; making the most important economic systems highly vulnerable. The dry land mixed-crop livestock systems such as the Central Rift Valley areas are prone to high climate variability and frequent drought events. Climate extremes are less of a risk in the highlands although they pose significant yield reduction, landslide and soil erosion. Recent studies have shown that flood hazard is increasing in the highland areas due to changes in land use/land cover, rainfall pattern, and drainage (Kassa, 2014). The recent past flood of 2006, for example, claimed 719 human lives, displaced over 241,699 people (Table 1), severely damaged infrastructures and houses, and caused property loss worth million USD across the country (Tadesse and Dagnachew, 2006; DDAEPA, 2011).

**Table 1.** Number of people affected by flood damage in the main rainy season of 2006

Region	Affected	Displaced	Casualties
Dire Dawa	9,927	9,927	256
SNNPR	106,666	28,775	368
Amhara	97,824	37,863	3
Somali	361,619	125,000	80
Oromia	20,156	3,392	10
Afar	42,100	4,050	-
Gambella	30,915	30,915	2
Tigray	582	582	-
Harari	3475	-	-
Total	674,479	241,699	719

Source: Demessie, 2007

## **2.2. Impact on crop production**

Although crop area, yield and productivity are increasing at a national level, currently, climate change is expected to have significant effects on crop production in the medium to long term period if the present rates of global warming continue unabated. Experiments and model predictions have shown that climate change through increased atmospheric CO<sub>2</sub> concentration, and the resulting rise in temperatures and changes in rainfall pattern, amount and variability affect crop production negatively in a multifaceted way.

Increased carbon fertilization of crops is reported to affect crop production positively especially in C<sub>3</sub> species. Increased CO<sub>2</sub> concentration increases yield by increasing rate of photosynthesis, leaf area index, and accumulation of non-structural carbohydrates, biomass and decreasing stomatal conductance and transpiration loss of water (Chauhan et al., 2014). You and Ringler (2010) projected 8-10% increase in agricultural GDP of Ethiopia due to fertilization of 482-532 ppm CO<sub>2</sub> by 2050. On the other hand, elevated CO<sub>2</sub> negatively affects crop production by decreasing the carbon to nitrogen ratio (Chauhan et al., 2014).

Unlike CO<sub>2</sub>, elevated temperature affects crop production negatively by increasing rate of respiration; hastening plant growth and development; increasing rate of water loss by increasing evapo-transpiration; and decreasing nutrient use-efficiency through increased rate of decomposition and mineralization. Likewise, the increase in rainfall affects crop production negatively in Ethiopian highlands by increasing flooding, water logging, run off, soil erosion and nutrient leaching. Contrarily, decreasing rainfall affects crop production by creating water deficit conditions.

### **2.2.1. Impact on length of crop growing period (LGP)**

An increase in temperature, as a manifestation of climate change affects duration of crop growth by slowing or hastening growth and development. Under cool climatic condition, for instance, the process of crop growth is slow and takes longer time to finish life cycle from germination to senescence. Slow growing process during vegetative phase allows the crop to have more photosynthetic time to accumulate more assimilates. Crops will also have

time at grain filling stage to translocate assimilates from source to sink to produce heavy size grains and thereby high yield. Conversely, under warm temperature conditions, the rate of internal metabolic process is higher with hastened growth and development resulting in early maturity. As a result, crops will have less time for vegetative growth to produce enough assimilates and also shorter time to mobilize assimilates to fill their sink at grain filling stage which results in small size and shriveled seeds at harvest.

There are no detailed studies on how climate change affects LGP in the different parts of the country. A recent study on maize in the Central Rift Valley of Ethiopia using two crop simulation models (DSSAT and WOFOST) under various climate change scenarios predicted a reduction of maize growth duration by 14-33 days by 2050 compared to the present, due to higher temperature and variable rainfall conditions (Kassie et al., 2014; Table2).

**Table 2.** Predicted changes in maize growth duration (in days) under the various climate change scenarios in the Central Rift Valley, Ethiopia

Crop model	GCM					
	CanESM4.5	CSIRO-MK4.5	HadGEM4.5	CanESM8.5	CSIRO-MK4.5	HadGEM8.5
DSSAT	-16	-23	-26	-25	-27	-31
WOFOST	-14	-23	-28	-26	-28	-33

Source: Kassie et al., 2014

Another study in the Tigray Regional State indicated a decrease in the LGP by 14–26 days in 2030s and 2050s in some areas (Alamata and Mekelle) but an increase in others (e.g., Maichew, Adigrat, Edaghamus and Shire (Hadgu et al., 2014).

### 2.2.2. Impact on suitable production area

One of the major expected effects of climate change on crop production in Ethiopia is relocation of suitable area of production for different crops. Under warming scenarios, plant species are forced to relocate growing areas to remain within optimal thermal zone (Mekasha et al., 2013). As species relocate habitat area, there may be net gain or loss of area of adaptation and production. In line with this, Evangelista et al. (2013) showed that by 2020




the major cereal crops of Ethiopia such as maize, tef, sorghum and barley will lose over 14, 11, 7 and 31% of their current suitable area of production, respectively. For maize, tef and barely this will be expected to increase to over 18, 11 and 37% by 2050, respectively. This indicates that C4 species (maize, sorghum, millet and tef), which are originated in warm tropical environments will reach near to their upper limit of maximum temperature tolerance and a small increase in temperature over the present maxima will displace them from their current adaptation area, and hence the areas used to be planted to these crops will be out of production (at least for the crops mentioned). Apart from C4 crops, C3 species, which are adapted to cool temperature, will be most affected by projected climate change (Table 3). This is because C3 crops like barley and wheat are grown over small areas in the highlands and relocation of growing areas upward along altitudinal gradient will further reduce suitable area available for the crops due to the natural decline in area available, with increase in altitude. As a result, wheat is also expected to lose significant area of its current production including where rainfall is expected to increase (Waithaka et al., 2013). Projections done by Waithaka et al. (2013) shows new patchy areas of maize production in the eastern parts of Amhara and Tigray, with an equal loss of maize production in the southwestern and eastern parts of central Ethiopia. While sorghum may gain substantial area of production in central Ethiopia and isolated areas towards the north, it will lose its current area significantly in the southern and south eastern regions of the country by 2020s (Waithaka et al., 2013).

**Table 3.** Predicted average %age change in area of production of major crops at national level in Ethiopia in response to climate change projected using CCCMA, HadCM3 and CSIRO GCMs under the A2 and B2 emission scenarios

Crop	Predicted net change in potential area of production (%)				
	2020		2050		
	A2	B2	A2	B2	
Maize	-14	-21	-25	-17.7	
Tef	-11	-12	-17	-11.2	
Sorghum	-7	-12	-7	-3	
Barley	-31	-36	-46	-37	

Source: Evangelista et al. (2013)





However, another study on the impact of climate change on maize in Africa by 2050s indicated an increase in maize area by 2.1-5.4% at a national level due to the expansion of maize to the highland areas compared to the baseline period, 2000s (Tesfaye et al., 2014).

Davis et al. (2012) performed a bioclimatic modelling on Arabica coffee in Ethiopia and examine future distribution with the HadCM3 climate model for three emission scenarios (A1B, A2A, B2A) over three time intervals (2020s, 2050s, 2080s). The models show a profoundly negative influence on indigenous Arabica coffee. In a locality analysis, the authors found the most favorable outcome to be a c. 65% reduction in the number of pre-existing bio-climatically suitable localities, and at worst an almost 100% reduction, by 2080s. In an area analysis, the most favorable outcome was a 38% reduction in suitable bioclimatic space, and the least favorable was a c. 90% reduction, by 2080s (Davis et al., 2012). Based on known occurrences and ecological tolerances of Arabica, the authors conclude that bioclimatic unsuitability would place populations in peril, leading to severe stress and a high risk of extinction.

### **2.2.3. Impact on crop productivity**

The ultimate goal of crop production is to get optimum/maximum yield of interest through combination of better crop genetic, environmental and management factors. Environmental climatic factors such as temperature, moisture, radiation and CO<sub>2</sub> directly affect phenological and physiological processes involved in biomass and grain development. The increase in concentration of atmospheric CO<sub>2</sub> is expected to be beneficial for yield increment as a whole. Nevertheless, an increase in temperature will offset a yield advantage from CO<sub>2</sub> fertilization, which is even worse when accompanied with water deficit. In Ethiopia, model predictions have shown that climate change will affect grain yield significantly and the effects are variable with crop and region. For example predictions by Kelbore (2012) showed that at national level yield of maize will increase by about 10% in the mid-century (2050), but decline by end of the century (2100). The same models predicted declining yield of wheat throughout the century (Table 4).

**Table 4.** Predicted change in national crop productivity of major crops in Ethiopia in response to projected climate using CGCM2, PCM, and HadCM3 GCMs under the A2 and B2 emission scenarios

Crop	Predicted %age change in national production (%)	
	2050	2100
Maize	10.84	-1.14
Wheat	-6.21	-11.03
Tef	-2.43	-1.09

Source: Kelbore (2012)

At regional level models projected an increase in maize yield by 48% in Amhara region in the mid-century and by 2% in Oromia region by end of the century. Nevertheless, models predicted a decreasing yield for wheat and tef with much reduction (17%) in the SNNP region in case of wheat (Table 5). Similarly using SWAT model, Mohammed (2009) predicted a 35 and 20% yield reduction in wheat by 2020 and 2050, respectively at Anjeni, North West Ethiopia. The same model predicted a yield reduction of 12 and 7% for tef in 2020 and 2050, respectively (Mohammed, 2009).

**Table 5.** Comparative predicted %age change in grain productivity of major cereal crops among the three major grain producing regional states of Ethiopia in response to projected climate change using CGCM2, PCM, HadCM3GCMs under the A2 and B2 emission scenarios

Crop	Year	Projected %age change at regional level		
		Oromia	Amhara	SNNP
Maize	2050	-1.51	47.86	-3.09
	2100	0.18	-0.21	-8.19
Wheat	2050	-7.26	-0.19	-17.04
	2100	-9.59	-12.3	-17.23
Tef	2050	-3.58	-1.93	1.89
	2100	-1.62	-0.66	-0.28

Source: Kelbore (2012)

Waithaka et al. (2013) using DSSAT model found substantial reduction in wheat yields even where rainfall is expected to increase, presumably owing to heat stress while there will be 25% gain in maize yield in the eastern highlands at the edge of Great Rift Valley as well as in the north central highlands. The same model showed a yield reduction of rain-fed sorghum over large areas in the western and north western part of the country. As a result 5-25% yield decline is expected in the western parts of Tigray, Amhara, Oromia, and SNNP as well as the whole of Benishangul Gumuz and Gambella states. Over large areas of Gambella, the yield decline might be exceeding 25%. On the other hand, more than 25% increase in sorghum yield is expected in central Ethiopia and isolated areas in the northern part of the country (Waithaka et al., 2013).

In another study, Jones and Thornton (2003) projected reduction in national maize yield by 3.4% in 2055 with localized areas experiencing yield loss or gain. On the other hand, a study by Tesfaye et al. (2014) using DSSAT model indicated an increase of maize yield by 0.6-2.8% at national level in 2050s depending on climate model and crop management scenarios with the yield increase or decrease varying greatly across the current maize growing areas of the country.

At local level, Welde kidane(2010)revealed that the total average grain yield of maize might decline in the range of 21-51% by 2090 in the Adama district of the Central Rift Valley region of Ethiopia using the CropSyst crop simulation model where Kassie (2014) also reported similar maize yield reduction using different models (Table 6).

**Table 6.** Response of maize yield to climate change projected using three GCMs by 2050 in the Central Rift Valley of Ethiopia

Crop model	RCPs	GCM	Yield change (%)
DSSAT	RCP 4.5	CanESM2	-2.6
		CISRO-MK3	-29.2
		HAD GEM2	-19.5
	RCP 4.8	CanESM2	-12.6
		CISRO-MK3	-27.1
		HAD GEM2	-22.7
WFOST	RCP 4.5	CanESM2	-2.4
		CISRO-MK3	-29.0



		HAD GEM2	-21.7
	RCP 4.8	CanESM2	-12.5
		CISRO-MK3	-26.9
		HAD GEM2	-29.4

Source: Kassie (2014)

Despite many interesting results have been recorded for both future climate scenarios and associated impacts, it is difficult to determine the trend or direction of the future impacts of climate change on area, productivity and production of crops in Ethiopia. This also implies that future climate change may carry with it opportunities too, for instance, new production belts (bright spots) might appear.

#### 2.2.4. Impact on crop disease and pests

At a global scale, pests and diseases attribute to an average yield loss of 18% and 16%, respectively in major crop species (IPCC, 2014). Climate change will alter potential losses to many pests and diseases as changes in temperature can result in geographic shifts through changes in seasonal extremes. Although, evaluation of climate change impacts on crop pests and diseases is difficult, owing to lack of long-term data sets, studies, some studies highlight the potential impact of climate on crop diseases and pests. For example, wheat rust risk, a major threat to wheat production in Ethiopia in recent years, has been observed to respond to ENSO (Scherm and Yang, 1995). Changes in climate are expected to affect the geographic range of specific species of insects and diseases for a given crop growing region. Climate change may also influence the migration of agronomic and invasive weeds species which possess characteristics that are associated with long-distance seed dispersal, and it has been suggested that these species may migrate rapidly with increasing surface temperatures (IPCC, 2014). To date, studies on the impacts of climate change on crop diseases, pests and weeds in Ethiopia are not available.

### 2.3. Impact on agricultural water resources

Ethiopia is endowed with enormous water resource from rivers, lakes and underground. The country has over 122 billion m<sup>3</sup> surface water from rivers



and 2.6 - 6.5 billion m<sup>3</sup> of ground water potential (Awulachew et al.,2007) with an estimated 5.3 million ha irrigable land (Negash, 2012). So far, only 5% of this vast potential is used for irrigation and the major crops grown by irrigation are industrial and cash crops with small proportion of food crops (Hordofa, 2008). Ethiopia's water resources depend on rainfall and are characterized by high spatial and temporal variability (Negash, 2012).

As have been seen in the preceding section, a changing temperatures and rainfall variability, will affecting both the supply and demand side of the agricultural water. In some areas of the country, annual rainfall is projected to decrease while increases are expected in others (McSweeney, 2008). The decrease in rainfall amount will cause decrease in ground water recharge, flow of streams and rivers thereby resulting in a declining amount of water available for irrigation. In other places, total rainfall may increase but will fall within a short period with greater intensity so that dry spells are longer. Higher temperatures will increase evapo-transpiration so that there will be increased loss of water –exacerbating drought phenomenon by offsetting advantages of increasing rainfall in some areas. A study conducted by Setegn et al. (2011) over the northern highlands of Ethiopia revealed that the actual evapo-transpiration (AET) will increase by 7-16.1% by 2045-2065 and this will increases to 8.1- 16.9% by 2080-2100, negatively affecting soil water balance, ground water and subsequently stream flow (Table 7).

**Table 7.** Projected annual change in actual evapotranspiration (AET), soil water, ground water and stream flow due to changes in climate by 2046-2065 and 2080-2100 periods in the Northern Highlands of Ethiopia

GCM	SERES	% change in AET		% change in soil water content		% change in ground water		% change in stream flow	
		2046-2065	2080-2100	2046-2065	2080-2100	2046-2065	2080-2100	2046-2065	2080-2100
ccccma	A1B	10.2	9.1	-1.18	-0.85	-50	-45	-33	-28
ccccma	A2	7.3	12.6	-0.93	-1.47	-52	-67	-33	-53
ccccma	B1	9.8	8.6	-0.7	-0.86	-20	-49	-17	-29
Mpi	A1B	9.7	14.1	-0.81	-1.32	-14	-18	-1	-3
Mpi	A2	9.6	15.3	-0.69	-1.42	-8	-25	7	-5

Mpi	B1	5.9	8.9	-0.59	-0.93	-10	-8	2	5
Gfdl	A1B	8	6.9	-0.84	-0.98	-34	-33	-19	-10
Gfdl	A2	9.2	14.9	-0.75	-1.2	-30	-40	-16	-17
Gfdl	B1	16.1	12.5	-0.47	-0.82	-10	-12	-1	-5
Ncar	A1B	10	13.8	-0.83	-1	-20	-10	-13	-10
Ncar	A2	11.1	16.9	-0.87	-1.4	15	38	15	55
Ncar	B1	7.5	8.1	-0.47	-0.8	-2	12	2	4

Source: Setegn et al. (2011)

## 2.4. Impact on livestock

### 2.4.1. Introduction

Climate affects animal production in three major ways: (a) The direct effects of weather and extreme events on herd body conditions and dynamics (b) indirectly, impacts on pastures and forage crop production and quality; (c) changes in the distribution of livestock diseases and pests could be substantial. The direct effects include temperature and other climate factors such as shifts in rainfall amounts and patterns on animal growth, reproduction and milk production (Thornton et al. 2008; Hoffmann, 2010). The indirect effects include climatic influences on availability of water, the quantity and quality of animal feed such as pasture, forage, crop yield and the severity and distribution of livestock diseases and parasites (Thornton et al., 2008; Sere et al. 2008).

### 2.4.2. Impact on Herd dynamics

Studies conducted in Ethiopia showed that climate change will have a negative impact on livestock population dynamics, in southern Ethiopia, cattle numbers dropped by 37% after the drought of 1983 to 1985. The herd then quickly grew to about 85% of the previous peak size by 1990. Another drop occurred in the early 1990s with a 42% reduction in cattle numbers, but the corresponding change in annual rainfall was less apparent in the early 1990s compared to that observed in 1983 to 1985 (Abdeta and Oba 2011; Solomon and Coppock, 2002). The general pattern showed that cattle population dynamics resembled a “boom and bust” pattern where

longer periods of gradual herd growth were punctuated by sharp crashes in 1983 to 1985, 1991 to 1992, and 1998 to 1999 when 37 to 62% of the cattle population perished (Alemayehu and Fentahun, 2012; Abdeta and Oba, 2007) (Figure 1). Droughts of the 1980s and 1990s caused 49% herd losses under the communal land use, while 57% of the cattle mortality under ranch management was attributed to droughts of the 1990s(Alemayehu and Fentahun, 2012). Cattle herd dynamics is strongly influenced by rainfall variability in southern Ethiopia (Alemayehu and Fentahun, 2012).

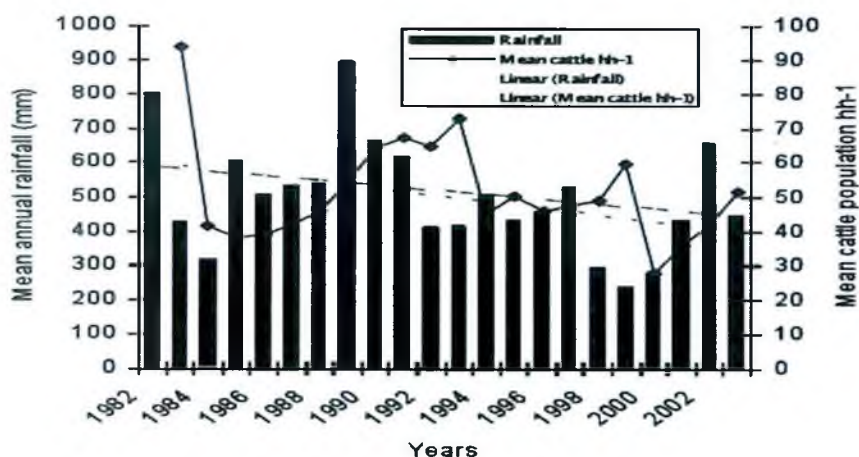


Figure 1. Relationship between inter-annual rainfall variability and cattle herd dynamics (Source: Alemayehu and Fentahun, 2012)

### 2.4.3. Animal feed and forage

Information is lacking on the effect of climate variability on availability of animal feed such as forage quality and quantity, species composition and nutrient content. However, it is expected that as temperature change, optimal growth ranges for different forage species also change; species alter their competition dynamics, and the species composition of mixed grasslands changes (Thornton et al., 2008). Citing Hopkins and Del Prado (2007), Thornton et al. (2008:2010) noted that climate change can be expected to have several



impacts on feed crops and grazing systems including the following.

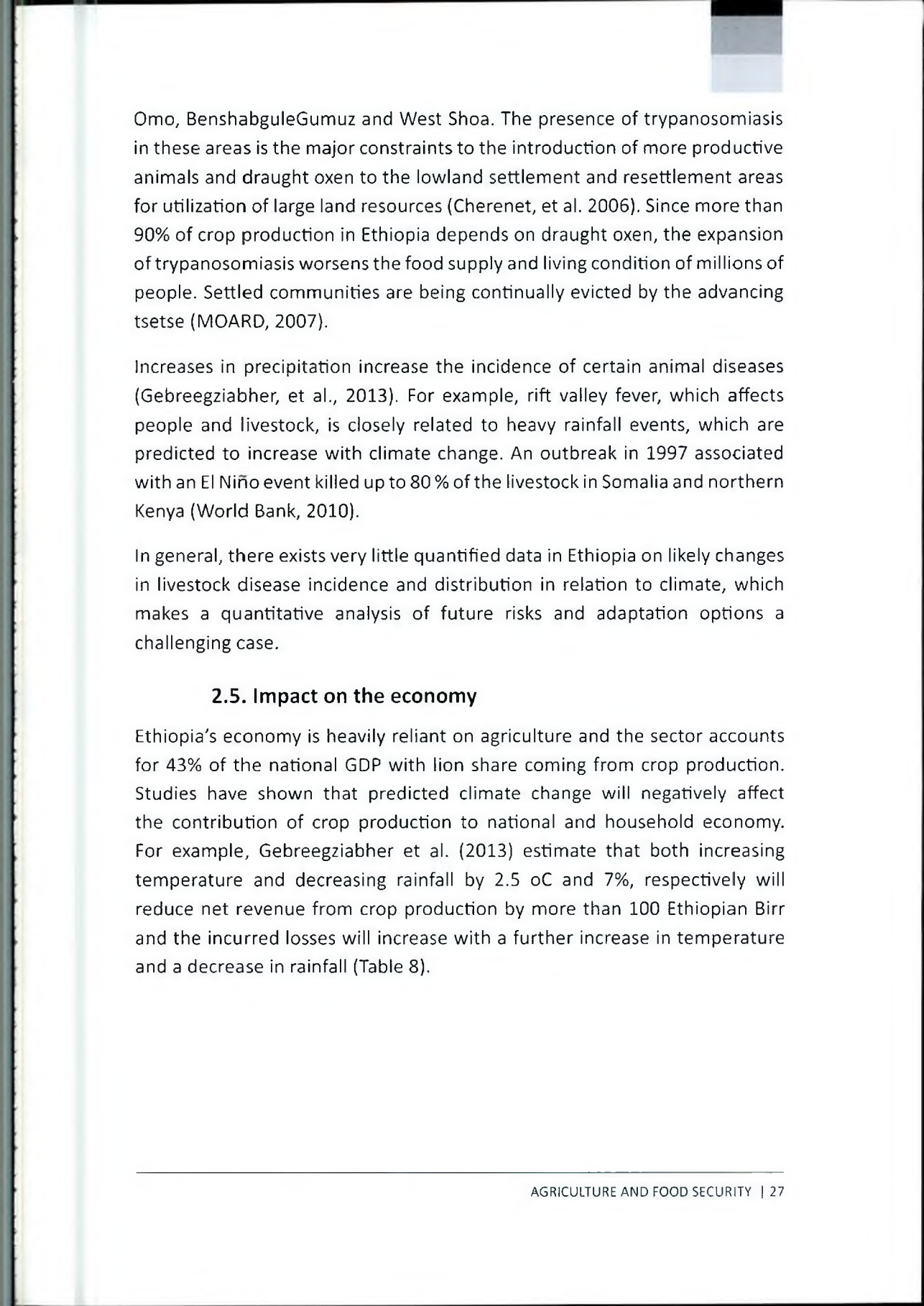
- Changes in herbage growth brought about by changes in atmospheric CO<sub>2</sub> concentrations and temperatures;
- Changes in the composition of pastures, such as changes in the ratio of grasses to legumes;
- Changes in herbage quality, with changing concentration of water-soluble carbohydrates and N at given dry matter (DM) yields;
- Greater incidences of drought, which may offset any dry matter yield increase;
- Greater intensity of rainfall, which may increase N leaching in certain systems

Sere et al. (2008) reported that large parts of Africa and Central Asia are likely to experience reduction in the length of growing period as a result of increased temperatures and lower rainfall. This is likely to lead to lower crop yields and reduced grazing land productivity, thus affecting the provision of feeds for animals. Thus, crop losses due to extremes in climate (temperature and rainfall) could result in less animal feed (crop residue) being available, especially in crop-livestock systems that predominates in the Ethiopian livestock production.

#### **2.4.4. Impact on livestock diseases**

The indirect effects of climate change on livestock include, for example, higher temperatures and changing rainfall patterns, which could translate into increased spread of existing vector-borne diseases and macro-parasites, accompanied by the emergence and circulation of new diseases (FAO, 2008). Under climate change, rising temperatures are changing the geographical distribution of disease vectors which are migrating to new areas and higher altitudes. For example the tsetse fly distribution in Ethiopia entails a gradual encroachment of the country's central highland plateau (Slingenbergh, 1992). Data from different sources indicated that the amount of land infested by tsetse fly in Ethiopia 22 years ago was estimated between 66,000 to 97,855 km<sup>2</sup> (MOA, 2001, citing Ford et al., 1976). This figure increased in 15 years-time to some 135-180,000 km<sup>2</sup> (Slingenbergh, 1992) and 220000 km<sup>2</sup> (National Tsetse and Trypanosomiasis Investigation and Control Center, NTTICC, 2004). These areas lie in Keffa, Illubabore, Western Wellega, North





Omo, BenshabguleGumuz and West Shoa. The presence of trypanosomiasis in these areas is the major constraints to the introduction of more productive animals and draught oxen to the lowland settlement and resettlement areas for utilization of large land resources (Cherenet, et al. 2006). Since more than 90% of crop production in Ethiopia depends on draught oxen, the expansion of trypanosomiasis worsens the food supply and living condition of millions of people. Settled communities are being continually evicted by the advancing tsetse (MOARD, 2007).

Increases in precipitation increase the incidence of certain animal diseases (Gebreegziabher, et al., 2013). For example, rift valley fever, which affects people and livestock, is closely related to heavy rainfall events, which are predicted to increase with climate change. An outbreak in 1997 associated with an El Niño event killed up to 80 % of the livestock in Somalia and northern Kenya (World Bank, 2010).

In general, there exists very little quantified data in Ethiopia on likely changes in livestock disease incidence and distribution in relation to climate, which makes a quantitative analysis of future risks and adaptation options a challenging case.

## **2.5. Impact on the economy**

Ethiopia's economy is heavily reliant on agriculture and the sector accounts for 43% of the national GDP with lion share coming from crop production. Studies have shown that predicted climate change will negatively affect the contribution of crop production to national and household economy. For example, Gebreegziabher et al. (2013) estimate that both increasing temperature and decreasing rainfall by 2.5 oC and 7%, respectively will reduce net revenue from crop production by more than 100 Ethiopian Birr and the incurred losses will increase with a further increase in temperature and a decrease in rainfall (Table 8).

Table 8. Economic impact of projected climate change on net revenue earning from crop production

Climate change scenarios	Change in net revenue (in ETB)
+5 0C Temperature	-3039.67
-7% in precipitation	-1609.01
-14 % in precipitation	-2676.71

Source: Gebreegziabher et al., 2013.

The work of Deressa and Hassan (2009) also showed decreasing annual revenue with an increase in both temperature and rainfall indicating that increasing temperature would offset positive effects of rainfall on revenue. However, they found seasonal differences, where increase in spring (Belg) and fall (Meher) temperatures will have positive effect, whereas temperature increase during winter (Bega) and summer (Kiremt) will have significant negative effects. The increase in spring and summer rainfall will have positive effect while the winter and fall increase will have negative effect on net revenue earnings from crop production (Table 9).

Table 9. Marginal impact of climate change on net revenue per hectare (US\$) in Ethiopia

Seasons	Winter	Spring	Summer	Fall	Annual
Temperature	-997.85***	375.83	-1277.28**	1877.69***	-21.61
Rainfall	-464.76***	225.08***	18.88	-64.19	-322.75***

\*\* Significant at 5%;\*\*\* significant at 1%; Source: Deressa and Hassan (2009)

In general, Ethiopia has low water storage capacity (1.5% and 1% of the water resource) (Awulachew et al., 2009; UNDP, 2011) with an average per capita water storage capacity of 50m<sup>3</sup>, compared to the 4170m<sup>3</sup> for an Australian farmer. The major food crops are produced under rain-fed which is highly influenced by the spatial and temporal variability of rainfall (Evans, 2012). Therefore, rainfall variability and associated yield reductions are estimated to cost the country around 38% of its potential growth rate and increase poverty by 25% (World Bank, 2006). Climate change could reduce GDP by 3-10% by 2025 (Evan, 2012).

A marginal impact analysis indicated that a 1°C increase in annual temperature will lead to statistically significant change in net revenue of -1577.72 Birr from crop agriculture, 282.09 Birr from livestock production, and -694.15 Birr from total agriculture inclusive of livestock (Gebreegziabher et al., 2013). Results show that warmer temperature is beneficial to livestock agriculture, while it is harmful to the Ethiopian economy from the crop agriculture point of view (Table 10). Moreover, increasing/decreasing rainfall associated with climate change is damaging to both agricultural activities. For the Nile Basin of Ethiopia, an annual net gain of 183.19 and 88.75 Birr is expected from crop agriculture and from total agriculture, respectively. A net loss of 163.78 Birr is expected from livestock production (Gebreegziabher et al., 2013).

**Table 10.** Change in net revenue as a result of climate change on crop, livestock and whole agricultural activities in Ethiopia

Climate change scenarios	Change in net revenue (in ETB)		
	Crop	Livestock	Whole agriculture
+ 2.50C Temperature	-1812.43	-274.02	-1035.46
+5 0C Temperature	-3039.67	368.52	363.8
-7% in precipitation	-1609.01	-1112.45	-645.08
-14 % in precipitation	-2676.71	-1833.42	-1141.63

Source: Gebreegziabher et al., 2013; ETB = Ethiopian Birr


## 2.6 Impact on food security

A significant proportion of people in the crop dependent highlands are chronically food insecure (Evan, 2012). Moreover, climate change places more pressure on the food security of millions by reducing crop yields, increasing land degradation, and lowering water availability. For example, a bio-economic analysis using maize crop as a case study indicate that the number of food insecure people in Ethiopia would increase by up to 2.4 million by 2050 as a result of the impact of climate change not only on production but also on global agricultural import and export trade and prices (Tesfaye et al., 2014).

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### **3. Vulnerability of mixed crop-livestock systems to climate variability and change in Ethiopia**

Vulnerability is considered to be a starting point or a state (i.e., a variable describing the internal state of a system) that exists within a system before it encounters a hazard event (Maddison, 2006; Sewagegn, 2011). Although vulnerability is defined in many ways for different contexts (Gallopín, 2006; Füssel, 2007), this assessment report adopts the IPCC (2001) definition which states vulnerability as the degree to which a system is susceptible to or unable to cope with adverse effects of directional climate change, variability and extremes. Vulnerability assessment begins with descriptive analysis of the socioeconomic and environmental characteristics: exposure, sensitivity and adaptive capacity to climate change. Exposure is a character, magnitude and rate of climate variation to which a system is exposed while sensitivity refers to the degree to which a system responds to a given change in climate, both beneficial and harmful. Likewise, adaptive capacity refers to the degree to which adjustments in practices, processes or structures are made in order to moderate or offset potential damage or take advantage of opportunities created due to a given change in climate (McCarthy et al., 2001). Mathematically, vulnerability is expressed as the product of exposure and sensitivity minus adaptive capacity. A vulnerability index can be developed in order to rank different regions and communities or households based on their degree of vulnerability.

The vulnerability assessment in this report also included an approach that integrated the Livelihood Vulnerability Index (LVI) framed within the United Nations Intergovernmental Panel on Climate Change (IPCC) vulnerability framework, LVI-IPCC (Simane et. al., 2014). The LVI-IPCC offers a tool to assess climate vulnerability through direct household surveys that was developed by Hahn et al. (2009) and Mohan and Sinha (2010) in which a balanced weighted average approach is used (Sullivan 2002).

#### **3.1. Key drivers of vulnerability**

Vulnerability of agriculture to climate risk in Ethiopia has its root in various factors. The following section discusses both climate and non-climate related vulnerability drivers at local scales. This presumes that an aggregated national vulnerability statistics do not capture the complex distribution of vulnerabilities that is present at the local level.

### 3.1.1. Climatic drivers

#### 3.1.1.1. Global climatic drivers

Globally, the El Niño and La Niña (ENSO) events, shifts of warm tropical Pacific Ocean currents, can substantially affect seasonal weather patterns around the world. For Ethiopia, the tele-connectivity of the Pacific Ocean is a key driver of extreme events, i.e., drought, flood and frosts owing to influence of the seemingly tele-connection system of the giant Pacific Ocean (Barnston and Smith, 1996; Glantz, 2001).

Driven by this global factor, Ethiopia has been historically prone to extreme weather events, where rainfall is highly erratic, and most rain falls in convective storms, with very high intensity and spatially and temporally explicit variability. Since the early 1970s, the country has suffered seven major droughts, five of which led to localized famines, in addition to dozens of local droughts (Diao and Pratt 2007). Survey data show that between 1999 and 2004 alone, more than half of all households in the country experienced at least one major drought shock (Dercon et al.; 2005, cited in UNDP 2007). Estimations also show that between 2000 and 2007, the combined yearly direct cost of drought and flood, fluctuated between 370 million to 2.5 billion Birr (21 million to 146 million USD). The value of the largest recorded disaster losses amounts to about 4 % of crop-related agricultural GDP and 7.3 % of livestock related GDP (UNDP, 2011). The number of people who suffered from drought peaked at 14 million in 2003 and, in the period between 2000 and 2007 was never below 1.5 million persons. The floods of 2006 were the most disastrous, affecting about 1.7 million persons (UNDP, 2011). Oxfam estimates that drought costs Ethiopia roughly \$1.1 billion a year—almost eclipsing the total annual overseas assistance to the country (Oxfam International, 2009, cited in ACCRA document, 2010)). Major floods occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996, and 2006 (ICPAC, 2007).

Overall, periodic drought in Ethiopia causes severe reductions in food availability, putting government expenditures on food aid and emergency drought relief to swell during these periods. In recent years, the Ethiopian government has maintained records of expenditures on vulnerability and food security (VFS), which have typically increased during extreme droughts (e.g., 1999–2000 and 2003–2004).

### 3.1.1.2. Regional climatic drivers

The broad characteristics of the Ethiopian climate, with the recurring wet and dry seasons are determined largely by the annual movement across the country of the equatorial low pressure zones. The dry northeasterly winds and the moist winds of southwesterly origin typify the dry wet season climate pattern respectively (NMSA, 1996a & b). During November to January, when southeasterly winds persist, long periods of dry winds are experienced; while little or no cloud and low relative humidity. Between March and May (short rains), the weather becomes unstable and convergence of moist southeasterly winds originating from Indian Ocean with the weakening northeasterly air stream causing rainfall over southern Tigray, Bale Highland, Northern Shoa, Northern and Southern Wello, northwestern Shoa, Arsi, Bale, eastern and western Hararghie, Hadiya, Northern Omo and Kembata Tembaro zones.

Although the short rains contribute only 5–10% to the country's overall crop production, it supplies around 25–60% of the national food security needs. It is also during the short rains that most agricultural lands are planted to the long cycle crops (eg; maize and sorghum) that allow growth and development of the crops by merging the two seasons together.

On the other hand, with the exception of the southern and south eastern parts, Ethiopia receives rainfall during June-July-August-September (JJAS) period with the progression of the Inter-tropical Convergence Zone (ITCZ) towards northern Ethiopia on the Red Sea coast and Gulf of Aden side; thus contributing to the tune of 90–95% of the national crop production (Kidane et al., 2006). During this season, both the Atlantic and Indian Oceans contribute major rainfall to the country. The length of the rainy season varies over a period and place, depending on the length and duration of the predominant winds (NMSA, 1996a & b). More importantly, the space-time characteristics of the Ethiopian rainfall pattern are key indicators of both the potential productivity and vulnerability of agriculture.

### 3.1.1.3. Local climatic drivers

Forming part of the Greater Horn of Africa (GHA), Ethiopia is a country of natural contrasts. In terms of topography; the country has the largest



proportion of ( $\approx 45\%$ ) elevated land masses in Africa (Addis Ababa University, 2001, EDRI, 2013). Ethiopia's varied topography has traditionally been associated with three mega climatic zones. These traditional agro-climatic zones are known as Kolia (warm semiarid), less than 1500m above sea level; Woinadega (cool sub-humid temperate zone), 1500–2400m above sea level; and Dega (cool and humid zone), mostly greater than 2400m above sea level. As the population increased and agricultural activities expanded, two more zones were added at the extreme ends of the agro-climatic spectrum. These are Bereha (hot arid) and Wurch (cold and moist). Geographically also, Ethiopia can be subdivided into five mega agroecological zones based on moisture and land use: 1) drought-prone highlands with insufficient rainfall; 2) rainfalls sufficient highlands dominated by enset-based farming; 3) rainfall-sufficient areas mainly planted to cereal-based crops; 4) generally dry, pastoral lowland areas and 5) humid lowland areas further inland that primarily support crop farming.

According to both classifications noted above, agricultural areas have spatially explicit potential and/or degree of vulnerability. The Dega (cool and humid zone) with sufficient rainfall for instance, are of high potential productivity or less vulnerable while Kolla and dry pastoral areas are generally of low potential or highly vulnerable to climate risks. Therefore, specific geographic locations and topography provide a unique potential and/or vulnerability of Ethiopian agriculture to climate risks. Simane et al. (2014), for instance, reported analytical results on vulnerability in one of the steeply dissected highland region of North West Ethiopia. In this mountainous terrain, the prevailing climate conditions and the sensitivity of agricultural systems to climate variability can change over a distance of even a few kilometers. Notable spatial heterogeneity could also be seen in soil qualities, steepness of slope, and access to infrastructure to support transport, agricultural technologies, and capacity building.

### **3.1.2. Non-climatic drivers**

#### **3.1.2.1. Agricultural land use practices viz-a-vis land degradation**

Land use practices contribute to greenhouse gases emissions by affecting agricultural systems directly and/or indirectly. The main greenhouse



gases (GHG) emission drivers from the agricultural activities are those related to carbon (C) and nitrogen (N) global cycles, both from crops and livestock production, thus agriculture by itself is the main trigger of its own vulnerability through activities that enhance greenhouse gases emission to the atmosphere (CRGE, 2011). For instance, the prevailing traditional land use practices like the local maresha-plough system that inverts soils and exposes the same to erosion (300 t/ha/yr), the slash and burn practices and farming on steep slopes are both key symptoms of soil erosion/land degradation and reduced organic carbon stock (Temesegen et al., 2007). Average soil loss rates on croplands could reach as high as 42 t ha<sup>-1</sup> year<sup>-1</sup> but may reach 300 t ha<sup>-1</sup>yr<sup>-1</sup> in individual fields (Hurni, 1998). High rates of on-field erosion are particularly problematic, given that soil acidity is one of the major causes for land degradation (Simane et. al., 2014). More knowledge on the biological processes that promote GHG emissions from soil allows creating opportunities for agricultural development under friendly environmental conditions, where soil can act as a reservoir and/or emitter of GHG, depending on the balance of inputs and outputs.

As indicated in the CRGE strategy (2011), per capita emissions in Ethiopia are projected to increase from 1.9 ton today to 2.9 ton in 2030. In absolute terms, the highest increase – adding more than 100 Mega ton (Mt) in GHG emissions - will come from agriculture, followed by industry at 55 Mt and forestry at 35 Mt.

On the other hand, deforestation through conversion of swathes of forest lands into cropland (160,000 to 200,000 ha/year), which covers 49% of all forestry-related emissions, causing loss of soil organic carbon through exposure to sunlight is a key driver of vulnerability of Ethiopia's agriculture, resulting into competing claims between food security issues and friendly environment (CRGE, 2011). Overgrazing of communal lands is also a major contributor to the severe degradation of natural resources in the mixed crop-livestock systems. Overall, the annual costs of land degradation are estimated to be at least 2-3% of the GDP and the trend in land use practices in Ethiopia can result in a substantial removal of agricultural lands out of production system (ACCRA-Ethiopia, 2010).

### 3.1.2.2. Demographic drivers

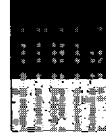
With a population of 84.9 million (UN, 2010), Ethiopia is the second-most populous country in Africa after Nigeria. With an annual population growth of 2% (0.5 million every year), Ethiopia will have more than 120 million people by 2030. Only 17% of the Ethiopians live in urban centres, almost half of those in the capital Addis Ababa (World Bank, 2009; 2011). About 8% of the population is believed to use some form of family planning (Funk et al. 2003, 2005) and 31% of the population is defined as undernourished. This is coupled with sporadic outbreaks of malaria, tuberculosis, Rift Valley Fever, various forms of flu and dysenteries that take away the productive labour forces (Funk et al., 2005). This contributes to the high vulnerability of agriculture to climate change.

### 3.1.2.3. Socioeconomic and technological drivers

Agriculture in Ethiopia is dominated by smallholder farmers and it contributes to more than 40% of the Gross Domestic Product (GDP) and 80% of the employment (CRGE, 2011). Despite fast growth in recent years, GDP per capita is still one of the lowest in the world, and the economy faces challenges from climate change. This arises from the vulnerability of the agriculture sector due its natural dependence on climatic conditions, the dominance of small-scale subsistence farmers with low levels of technology adoption, use of limited farm inputs, low access to finance/credit services, and inadequate transport networks and low climate and market information (EPACC, 2012). In terms of technological intervention, the research system has released more than 800 agricultural technologies during 2010-2015 GTP periods alone, but not all of them are resilient to climate variability and change showing the need for new level of thinking and alternative research strategies.

Limited national scientific, technological, financial and institutional capacity and arrangements and poor infrastructure collectively heightened Ethiopia's vulnerability to the impacts of climate change (UNDP, 2011). Moreover, Ethiopia is often referred to as the 'water tower' of Eastern Africa because of the many rivers that pour off the highlands. It also has the greatest water reserves in Africa, but unevenly distributed, with between 80-90% of the country's surface water falling within four major river basins located in the west and southwest of the country (Abay, Tekeze, Baro Akobo, Omo and Omo





Gibe). In the East and Central parts of the country where 60% of the population live, there are only 10-20% of the surface water resources. However, few irrigation systems are in place and Ethiopia has low water storage capacity. So far, only 1.5% and 1% of the water resource is used for irrigation and power production, respectively (Awulachew et al., 2009; UNDP, 2011).

Ethiopia's trade deficit amounts to almost 20% of the GDP. While exports of merchandise account for about 4%, import of goods comprise more than 23% of GDP (CRGE, 2011). Although more climate-compatible alternatives and opportunities might arise, thus offering higher social and economic benefits in the long run, the capital-constrained economies like Ethiopia are often inclined to invest in low capital expenditure (CAPEX) alternatives, and thereby lock themselves into obsolete solutions that are inefficient and ultimately become highly vulnerable to climate change.

#### 3.1.2.4. Poverty

Despite observed rapid growth over the recent years noted in Ethiopia, the population remains one of the poorest in the world. Imported food aid and short-term emergency relief interventions are still form major manifestations of tackling the chronic food insecurity, thus referring to the need for addressing the analyses of poverty as an underlying cause of vulnerability (UNDP, 2011). In practice, the link between poverty and vulnerability depends on the dimension of the risk and the assets available to cope with it. According to Dercon and Hoddinot (2003), shocks have had a persistent negative effect on economic growth in Ethiopia. In 2004, 44% the population was living below the poverty line and GDP per capita was 141 USD in 2005, about 20% of the Sub-Saharan Africa's average (World Bank 2006).

**Table 11.** Energy and total (absolute) and food poverty line (average price) in 2010/11

Factor	Values
Kilocalorie per adult per day (Kcal)	2200
Food poverty line per adult person per year (Birr)	1985
Total poverty line per adult per year (Birr)	3781.

Source: HICE survey (2010/2011) as cited in MoFED, 2012.

According to the Household Income Consumption and Expenditure Survey (HICES) (MoFED, 2012), the proportion of poor people (poverty head count index) in the country is estimated to be 29.6% in 2010/11 (Table 11). In 2010/11, while the proportion of the population below the poverty line stands at 30.4% in rural areas, it is estimated to be 25.7% in urban areas. The poverty gap index is estimated to be 7.8%, while it is 8.0% for rural areas and 6.9% for urban areas. Similarly, the national level poverty severity index stood at 0.031 with rural poverty severity index (0.032) being slightly higher than that of urban areas (0.027). Between 2004/05 and 2010/11, income (consumption) inequality measured by Gini Coefficient has shown a slight decline from 0.3 in 2004/05 to 0.298 in 2010/11. Inequality as measured by the Gini coefficient has declined in urban areas from 0.44 to 0.37, while rural inequality increased from 0.26 to 0.27, though inequality is still higher in urban than in rural areas.

### **3.2. Case studies on vulnerability of mixed crop-livestock system to climate change**

The following section presents empirical evidences from the diverse works done on vulnerability of Ethiopian agriculture to current climate variability and future climate change. The analyses have spanned a varying spatial scales; regional states level (Deressa et al., 2008), basin and watershed level (Legesse and SHEMELES, 2013; Simane et al., 2012; 2014), district and community levels (Tesso et al., 2012, Senbeta, 2009, Agromet team of EIAR, 2013), and household level (Deressa et. al, 2009).

#### **3.2.1. Case studies on exposure**

Some case studies conducted in Ethiopia show the exposure of the agriculture sectors at localized scales. Results from the exposure analysis by Legesse and SHEMELESE (2013) in Upper Awash Basin using four GCMs (CGCM3, HADGEM, MK3 and ECHAM5 data under A1B emission scenario revealed that there would be a change in rainfall and mean temperature by 2050 in the study area. The change in seasonal rainfall ranges from -5 to 3.7 % while average seasonal mean temperature changes ranges from 1.2 to

3.3 oC. This result was used as a proxy indicator for measuring exposure to future climate change in vulnerability analysis. The exposure index is related to the frequency of drought hazards. The results indicated that Dendi, Dawo and Welmera districts are highly exposed to the risk of drought and future change in temperature and rainfall while Ilu and Keresana Kondaltiti districts have relatively less exposure. The remaining districts are moderately exposed (Fig.2).

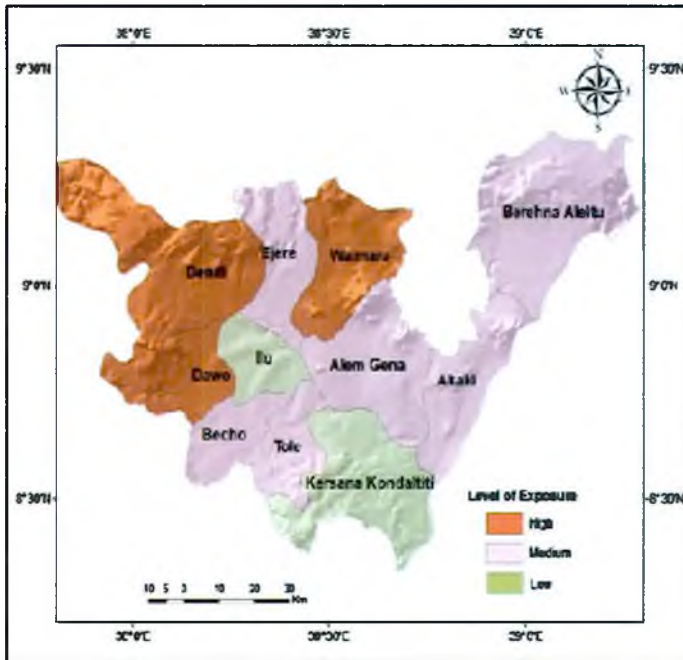
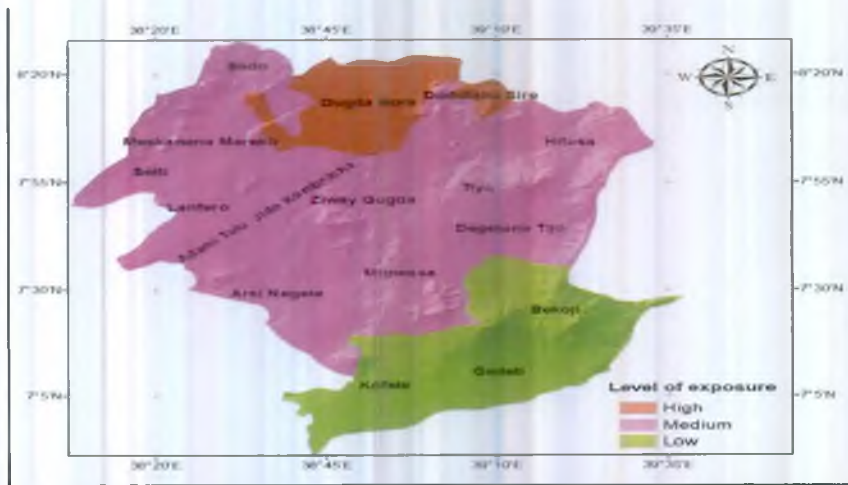


Figure 2. Exposure map of the Upper Awash Basin (Source: Legesse and Shmelese, 2013).

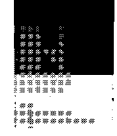




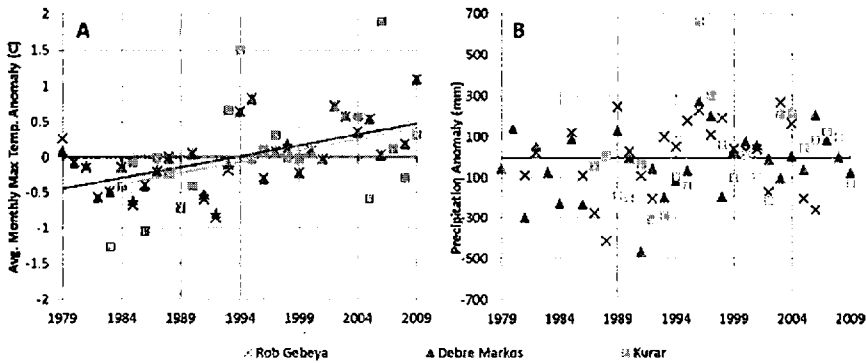
**Figure 3.** Exposure map in Central Rift Valley of Ethiopia (Source: Agromet team of EIAR, 2013)

A preliminary analyses of exposure by the Agromet team of EIAR (2013), in the Central Rift Valley indicated that Dugda Bora and Dodotana Sire districts are highly exposed to the risk of drought and future change in temperature and rainfall, while Kofele, Bekoji and Gedeb districts have relatively less exposure. The remaining districts are least exposed (Fig. 3).

The study of Simane et al., (2014) on exposure indicates that people living in different agro-ecological systems of Choke perceive climate change differently, even when the systems are in close proximity to one another. This is due to contrasts in local climate impacts, as well as due to differing socio-economic perspectives on these impacts (Simane et al., 2012). Generally, The Choke communities perceive an increase in extreme rain events and temperatures over the past 20 years. This perception on exposure is also linked to a high sensitivity of agricultural productivity in the study locality in which a declining trend in yield in some areas of the system and the move from food surplus to food deficit within the past 20 years (Simane et al., 2012; 2014) have been observed. About 85% of the respondents perceived that the temperature has increased over the last 20 years which is significantly different from zero in all



agro-ecosystems studied. The perceptions are consistent with observations since 1979 at stations located in low elevation, medium elevation, and high elevation (Fig. 4; Simane et al., 2012; 2014), showing a linear trends in average monthly maximum temperature in the order of 0.03 °C per year ( $\approx 0.3$  °C per decade)



**Figure 4.** Meteorological station records of (a) annually averaged monthly maximum temperature anomaly and (b) annual precipitation anomaly for Rob Gebeya (AES5), Debre Markos (AES3/4) and Kurar (AES1). AES = agro-ecosystem. Source: Simane et al., 2012.

About 61.3% of respondents in the Choke Mountain perceive a decrease in rainfall with perceptions differing less across agro-ecological zones. In terms of extreme weather events, 85.8 % of farmers claimed to have been hit by an extreme weather event, and that farmers at the highest altitudes are more vulnerable to extreme weather events than those at lower altitudes (Simane et al., 2012; 2014).

The exposure analyses of Senbeta (2009) in Arsi Zone shows that the trend of gradual and extreme weather change is particularly negative for the livelihood of people, in the mid and lowlands areas but has a positive role in some places where agriculture is already constrained by low temperature. On the other hand, drought, late rain onset, erratic nature of rainfall and heavy and unseasonal rain are also challenges to the livelihood of the entire zone (Senbeta, 2009).

### 3.2.2. Case studies on sensitivity

Results from the sensitivity analyses in the Upper Awash Basin by Legesse and Semelese (2013) revealed that Dendi and Dawo districts are relatively highly sensitive to the adverse impacts of climate change due to high human-environmental interactions caused by combined effects of large agricultural land owned by smallholder farmers, high dependency on agricultural activities and steep slope topography. The least sensitive districts are Ilu and Alem Gena districts (Fig.5).

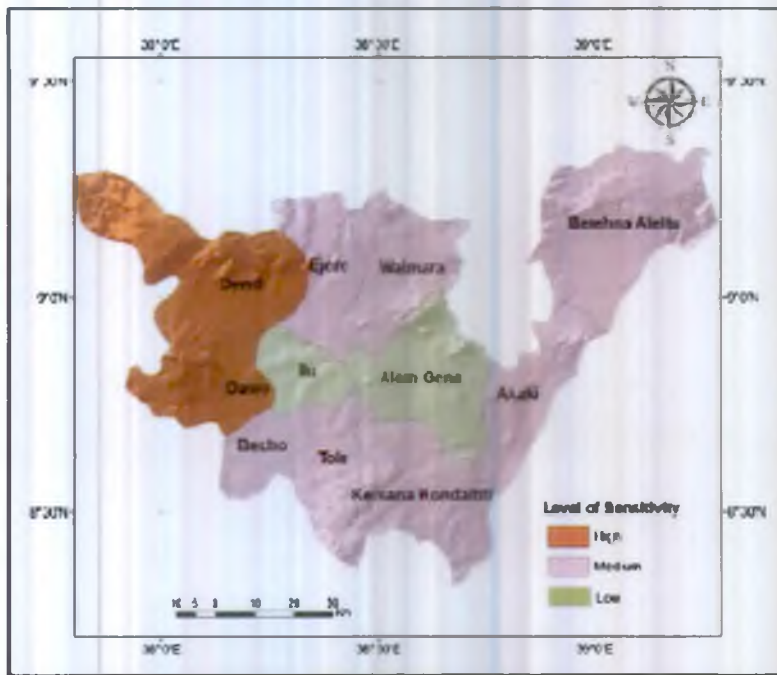


Figure 5. Sensitivity map of the Upper Awash Basin (Source: Legesse and Semeles, 2013).

The sensitivity analyses of the Agromet team of EIAR (2012) in the Central Rift Valley of Ethiopia, revealed that Hitosa and Tiyo experience high human environmental interactions due to high population density and small ratio of land holdings, and high dependency on rain-fed cropping system. The least sensitive districts are Dugda Bora, Adami-Tulu-Jido Kombolcha and Arsi Negele districts (Fig. 6). From the result, the overall sensitivity index holds higher weight, as the result of which the impacts of climate change on the livelihood of the farmers is expected to be more severe.



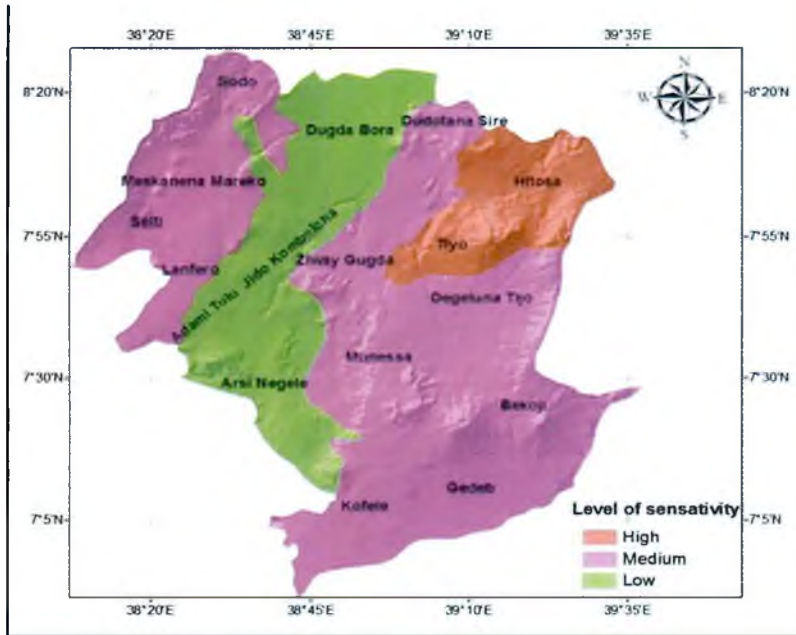


Figure 6. Sensitivity map of Central Rift Valley of Ethiopia (Source: Agromet team of EIAR, 2013)

Simane et al. (2014) reported different sensitivity levels among different agro ecosystems based on biophysical constraints (slope, soil fertility and depth, deforestation and land degradation) on productivity in the Choke Mountain. Land degradation has become one of the most important sensitive components of the Choke Mountain system, mainly due to soil erosion and nutrient depletion (Simane et al., 2014). In general, coupled with poverty and fast-growing population, land degradation poses a serious threat to national and household food security and increase the sensitivity of agriculture to climate change.

### 3.2.3. Case studies on adaptive capacity

Adaptive capacity at a given scale is assessed using wealth, technology, infrastructure, community and social capital as a major criteria. According to the Agromet team of EIAR (2013), adaptive capacity indices for sixteen districts in the Central Rift Valley (CRV) of Ethiopia show that most districts have medium level of adaptive capacity to climate change (Fig. 7). On the

other hand, Munessa and Lanfaro districts have higher adaptive capacity. This is mainly due to the combined effect of high level of literacy, crop productivity, farm asset, and use of credit and advisory services. Arsi Negele, Meskanena Mareko and Hitosa districts have lower adaptive capacity (Fig. 7). The result implies that both socioeconomic and infrastructural asset distribution are important to build capacity and to respond and manage to the climate risks.



**Figure 7.** Adaptive capacity map of Central Rift Valley (Source: Agromet team of EIAR, 2013).

Another case study in the Upper Awash Basin (Legesse and SHEMELESE, 2013) reveals medium level of adaptive capacity for most of the study districts (Fig. 8). Dawo and Tole districts have relatively higher adaptive capacity. This is mainly due to the combined effect of high level of literacy, crop productivity, farm asset, and use of credit (Legesse and SHEMELESE, 2013). Ejere, Alemgena and Kersana Kondaliti districts have relatively lower adaptive capacity, while the rest of the districts showing medium level of adaptive capacity. The result implies that both socioeconomic and infrastructural asset distribution makes the majority of the area to build adaptive capacity (Legesse and SHEMELESE, 2013).

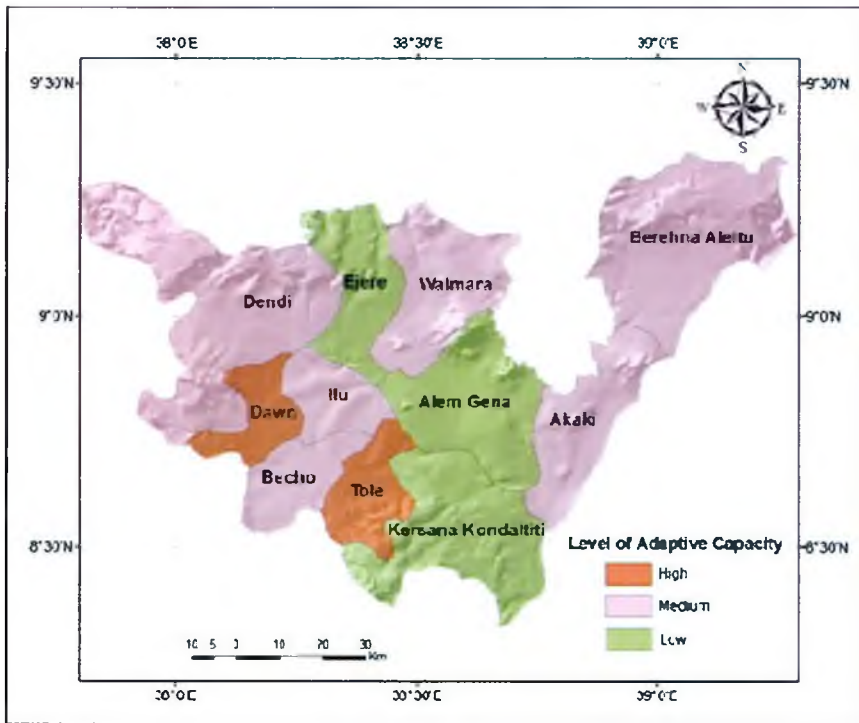


Figure 8. Adaptive capacity map for Upper Awash Basin (Source: Legesse and Shemelese, 2013).

Social institutions also play an important role in building the adaptive capacity of communities. Farmers with high institutional participation, many relatives in a community, family size with working potential, and participation in different social meetings usually lead to high social power to withstand adverse effects and result in better adaptive capacity in North Shewa Zone (Tesso et al., 2012). On the other hand, low literacy rate of communities, high dependency ratio of household members with more than four dependents (the proportion of dependent household member with less than 18 and greater than 60 years), low participation in different institutions increased the vulnerability level of community members to the frequently occurring natural shocks in the study area (Tesso et al., 2012).



Forming part of the adaptive capacity, the economic vulnerability analyses of farmers in North Shewa Zone shows that the large majority of the households operate under less diversified livelihoods. These include low non-farm engagement, low access to credit and market, small landholding, low holding of perennial crops, small or no area under irrigation; thus indicating a high level of economic vulnerability of farmers to shocks (Tesso et al., 2012). Hence, large majority of the farmers are economically vulnerable to the impact of climate change and that, 38.5% of the population (or 5 out of 13 rural districts of the zone) are recurrent beneficiaries of safety net program from year to year (Tesso et al., 2012).

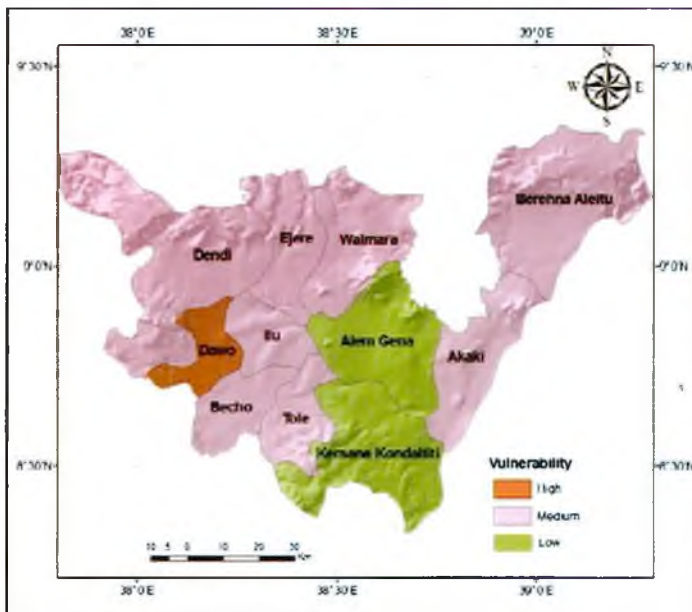
Case studies also indicate that natural assets such as agroecological settings, land size, livestock resources and access to irrigation and use of fertilizes and improved seed contribute to the adaptive capacity of farmers (Jahnke and Asamnew, 1983; Simane et al., 2014). Access to major indicators of infrastructure (i.e., access to road, first cycle primary school, veterinary services, market, credit services, electricity, and telephone) influence the adaptive capacity of farmers (e.g., Simane et al., 2014). In general, farmers with better investment on natural resource management, access to market, better social network, access to credit, preparedness, saving liquid assets, access to irrigation and better level of education exhibited greater level of resilience during and after climate change induced shocks (Tesso et.al (2012).

#### **3.2.4. Interaction among vulnerability components (exposure, sensitivity & adaptive capacity)**

Vulnerability assessment also opens room for the interaction studies among its components in which exposure influences sensitivity; which means that exposure to higher frequencies and intensities of climate risk highly affects outcomes (e.g., yield, income and health). Exposure is also linked to adaptive capacity such that better adaptive capacity reduces potential damages from exposure. Sensitivity and adaptive capacity are also interlinked; given a fixed level of exposure, adaptive capacity reduces the level of sensitivity. Integrated analyses of vulnerability components in agriculture have been reported by few researchers (Simane et al., 2014, Legesse and Shemelese, 2013; Tesso et al., 2012).

Results of integrated vulnerability analysis by Simane et al. (2014) in the Choke Mountain showed systematic differences in vulnerability across five agro-ecosystems in the study area. Overall, the results suggested that 30% of the total land mass (midland plains with black soil and mid land plains with brown soils) has relatively low vulnerability to climate change. However, about 62 % of the total land mass was categorized as having high relative vulnerability which included lowlands, valley fragmented areas and the mountainous highlands. The midland sloping lands were moderately vulnerable (Simane et al., 2014).

The integrated analyses of vulnerability components by Legesse and Semeles (2013) in the Upper Awash Basin revealed that Dawo district is relatively highly vulnerable to the impact of climate change while Alemgena and Kersana Kondaliti districts are less vulnerable (Fig. 9). The rest of districts are under relatively medium level of vulnerability to the impact of climate change.



**Figure 9.** Aggregate vulnerability map of Upper Awash Basin (Source: Legesse and Semelese, 2013).

Another study in the Central Rift Valley using the three components of vulnerability indicated different level of vulnerability among districts (Agromet team of EIAR, 2013). For example, Silte, Dodotana Sire and Tiyo districts are the most vulnerable to the impact of climate change while Arsi Negele, Adami Tulu Jido Kombolcha and Dugda Bora districts experience the lowest level of vulnerability because of their better adaptive capacity (Fig.10).



**Figure 10.** Aggregate vulnerability map of Central Rift Valley of Ethiopia (Source: Agromet team of EIAR, 2013).

The work of Deressa et al. (2008) shows that the net effect of adaptive capacity, exposure and sensitivity is positive for SNNP and Benhangul Gumuz and negative for Afar, Amhara, Oromia, Somali and Tigray. Whilst SNNP and Benishangul Gumuz are less vulnerable. (Fig 11), Afar, Amhara, Oromia and Somali are vulnerable to climate change with varying magnitude (Fig. 11). The lesser vulnerability of SNNP is explained by its relatively higher access to technology, as the percentage of farmers in this region have relatively better access to insecticides, pesticides, fertilizer, and supplies of improved seeds and food market, and its highest irrigation potential and literacy rate compared to mother regional states (Deressa et al., 2008). For Afar and Somali, vulnerability is associated with lower levels of rural service provision and infrastructure development. For example, a study in Borena zone



highlights low investment in services and infrastructure, inadequate policies and institutions as well as social and gender inequalities and environmental degradation (Deressa et al., 2008).

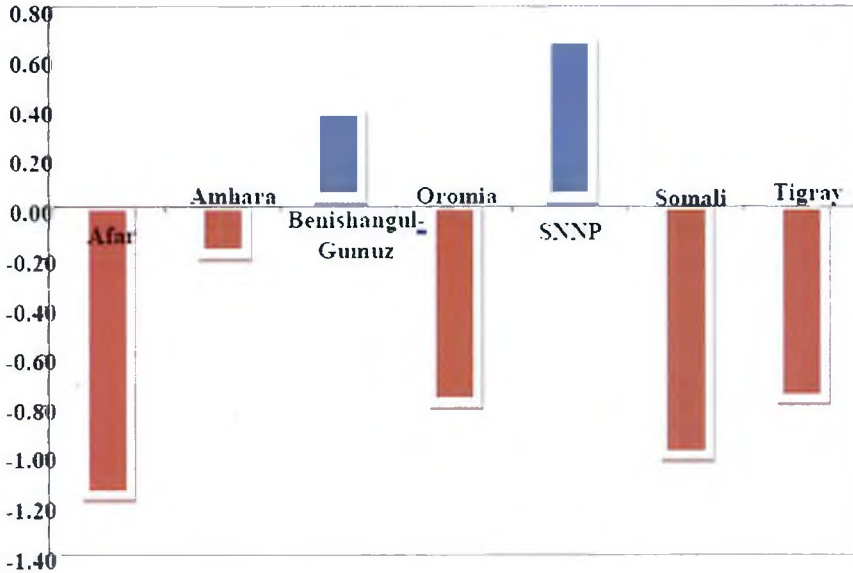
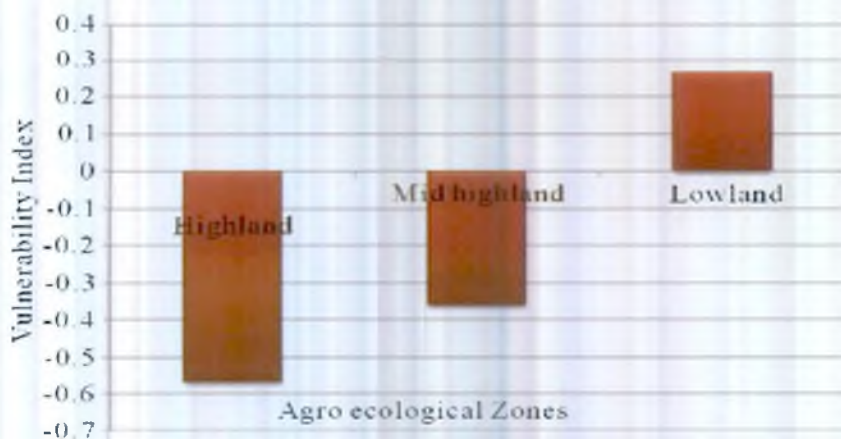


Figure 11. Vulnerability indices of the seven regional states of Ethiopia (Source: Deressa et al., 2008).

The analysis undertaken to compare the vulnerability of households across different agro-ecologies over different scenarios of poverty line indicate that farmers living in kola are the most vulnerable to climatic extremes. Policy-wise, these preliminary results indicate that, keeping other factors constant, increasing the incomes of farmers (with special emphasis on those in kola agro-ecological zones) and enabling them to meet their daily minimum requirements will reduce their vulnerability to climatic extremes (Deressa et al., 2009).

Contradictory to Deressa et al. (2008; 2009), the report by Tesso et al. (2012) found the highland agroecologies to be more vulnerable to the impacts of climate change than the low land ones (Fig. 12). The net effect of adaptive capacity, exposure, and sensitivity computed from the Principal Component Analysis of Tesso et al. (2012) shows that the net value is only positive for

communities living in the lowland areas while it is negative for those living in midland and highland agro-ecologies. The most vulnerable agro-ecology is the highland due to the smaller per capita land availability, highly fragmented parcel of farmland, low productivity of land due to impoverishment in soil fertility, high soil erosion due to farming on steep slopes, lower level of asset building (e.g., livestock and perennial crops), and generally lower level of experience to adapt to climate change impacts. This less vulnerability of the midlands than the highlands is attributed to lower level of prevalence of pest and diseases, potential to grow diversity of crops, relatively gentle sloping of farmlands, moderate rainfall and low frequency of natural hazards. In contrast to the expectations, the lowland agroecologies were not vulnerable when compared with the mid- and highland agroecologies. This could be due to better experience of operating agricultural activities under stressful conditions, relatively larger farm size with optimal number of farm plots, moderate slope of farm lands, better fertility level, better size of land under irrigation, better adaptation to changing climatic conditions and access to early warning information (Tesso et al., 2012).



**Figure 12.** Household vulnerability index to climate change impact in North Shewa (Source: Tesso et al; (2012)

According to Tesso et al. (2012), indicators for environmental vulnerability include, but not limited to slope of the land, soil fertility, rainfall, temperature, frequency of hazards (drought, flooding, forest fire, disease outbreaks, etc.),



vegetation cover, and others. In the overall vulnerability analysis model, these are variables for the measurement of sensitivity and exposure. Undulating and steeply sloping farmlands, low fertility level due to frequent degradation to soil erosion, extremely low vegetation cover, frequently occurring climate change induced shocks (at least 5 in a year), below average rain and mounting temperature have significantly contributed to the vulnerability level of smallholder farmers (Tesso et al., 2012).

Differences in vulnerability to climate change among household/community members have been reported. For example, the youth are found to be more vulnerable to climate change as compared to the elderly ones which could be explained by the difference in land holding and unemployment in North Shewa Zone (Tesso et al., 2012). Although the elderly have inherited land to their offspring, they are generally better off in land holding and have better immunity to cope with climatic shocks whereas the youth are generally poor because of unemployment and landlessness (Tesso et al., 2012). Women are also highly vulnerable to climate change because of their two fold household responsibilities, i.e low resource endowments, restrictive social institutions, and low access to information and extension services, among others.

### **3.2.5. Case studies on vulnerability as expected poverty**

Using vulnerability as expected poverty approach, Deressa et al. (2009) showed that the Ethiopian farmers' vulnerability is highly sensitive to their minimum daily requirement (poverty line). For instance, when the daily minimum income is fixed at 0.3 USD per day, only 12.4% of farmers are vulnerable to climate extremes, whereas 99% of farmers are vulnerable when the minimum requirement is fixed at 2 USD per day. Therefore, the number of people poor today and likely to be poor in the future increases with increasing minimum income level required to sustain daily life. When the poverty line is fixed at 0.3USD per day, most people have the characteristics that they are not poor today and are likely to remain above the poverty line in the future (Deressa et al., 2009).

The results further indicate that farmers in kola agro-ecological zones (which are warm and semi-arid) are the most vulnerable to extreme climatic events (Table 12). Of the total farm households surveyed in kola, 99.4% are vulnerable



at present or will be vulnerable in the future (fall above the 50 % cutoff line); whereas the remaining 0.36% of the farmers are not vulnerable at present or will not be vulnerable in the near future when the scenario of minimum daily income is fixed at 1.25 USD per day. The same line of explanation also holds for the rest of the scenarios across different agro-ecologies (Table 12).

Table 12. Vulnerability at basin level and across agro-ecological setting using different scenarios of poverty lines

Scenario (\$ US per day)	Nile Basin	Kola	Weynadega	Dega
2.00	0.93	0.97	0.91	0.93
1.50	0.86	0.94	0.85	0.82
1.25	0.84	0.93	0.82	0.76
0.30	0.07	0.11	0.08	0.02

Source: Deressa et.al., 2009.

The results indicate that increasing the incomes of farmers and enabling them to meet their daily minimum requirements will reduce their vulnerability to climatic extremes (Deressa et al., 2009).

In general, the foregoing case studies indicate the levels of exposure, sensitivity, and adaptive capacity of smallholder farmers to climate change and the associated vulnerability which vary with local agroecologies, socioeconomic conditions and other biophysical factors. However, because of lack of national level and/or regional level vulnerability analysis, it is difficult to draw concrete conclusion that indicated the vulnerability level of Ethiopian agriculture to climate change.



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## **4. Adaptation to climate change in the mixed crop-livestock systems**

### **4.1. General**

Historically, adaptation of agricultural systems to environmental changes has been the norm rather than the exception and societies have historically adapted to climate conditions (Adger, 2003; Lotze-Campen & Schellnhuber, 2009; Baethgen et al., 2004). However, the current speed of climate change is inducing and modifying known variability patterns beyond the coping capacity of systems (FAO, 2008). The increasing frequency and magnitude of extreme weather events coupled with unprecedented changes in the climate is also imposing new and potentially overwhelming pressure on the capacity of existing adaptation strategies (Ziervogel et al., 2008). Therefore, deliberate and conscious adaptation that can cope with these evolving impacts is an immediate concern in agriculture. Particularly in countries like Ethiopia, where agriculture is highly tied with climate, adaptation is a priority.

The essentiality of agricultural adaptation in Ethiopia is self-evidenced by agriculture's multiple roles in the country. Food security, employment, income and significant portion of GDP are drawn from agriculture. Agriculture accounts about 41 % of the GDP, 90 % of the exports, and serves as the direct source of employment and livelihood for about 85 % of the population (NMSA, 2001; FDRE, 2010). What makes such overwhelming reliance on agriculture a serious problem is overdependence on rainfall which is by no means immune to climate change. According to IPCC, unless effective adaptation strategies are carried out timely, some African countries could lose up to 50 % of yield from rain-fed agriculture by the year 2020 and access to food will be severely compromised in many African countries (IPCC, 2007a). Ethiopia cannot be an exception given its overdependence on climate driven economy. Such impacts that significantly undermine the prominent role of agriculture in food production and economic growth predominantly signify the criticality of adaptation.



## 4.2. Adaptation Practices in Ethiopia

This section explores climate change adaptation practices and options at macro and micro-levels. Adaptation in agriculture usually takes place at two broad scales: macro- and micro-levels (Kandlikar & Risbey, 2000). At macro-level, adaptation deals with adjustments of agricultural production systems at national and regional levels vis-à-vis domestic institutions, international policies, climatic factors, markets and other strategic issues. Whereas, at micro-level it is concerned with adjustments and decision making at farm level (Risbey et al., 1999; Kandlikar & Risbey, 2000; Kurukulasuriya & Rosenthal, 2003; Nhemachena & Hassan, 2007). On the other hand, adaptation might be proactive or reactive. Proactive adaptation is an adaptation that takes place to anticipatory climate stimuli; whereas reactive adaptation refers to an adaptation that takes place in response to already observed climate stimuli (IPCC, 2007b). Adaptation may also take various forms such autonomous (private/collective) and/or planned (public sector) adaptation. The review thus focuses on all forms of adaptation measures adopted at all levels without necessarily categorizing them into their respective forms.

Studies on climate change adaptation in Ethiopia are yet emerging. Nevertheless, there are some studies that documented adaptation strategies carried out by farmers. Most of the empirical studies focused on adaptation strategies at micro-level as 90% of the national agriculture is accounted by small-scale farmers. But, it has to be understood that these adaptation strategies might not be purely driven by climate change as agriculture adaptation also occurs in the context of economic, technological, social, and political forces that are difficult to isolate. Determining when climate is the driving force behind adaptation behavior is difficult, and thus it is widely acknowledged that most adaptation practices serve multiple purposes and are strongly interrelated (Smit & Skinner 2002; Adger et al., 2007).

On the other hand, since some consider climate change as a phenomenon yet to happen, adaptation occurring now is rather of due to climate variability. In contrast, evidencing the catastrophic drought of 1984-85, some climate researchers believe Ethiopia as one of the first victims of climate change (Philander, 2008). Hence, adaptation is already happening as a response to climate change along with climate variability and other non-climate factors.

That is why IPCC (2001, citing Mearns et al., 1997, Karl & Knight, 1998, Berz, 1999 and Hulme et al., 1999) stress climate variability as an integral part of climate change. Thus, adaptation to climate change necessarily includes adaptation to variability (Hewitt & Burton, 1971; Parry, 1986; Kane et al., 1992b; Katz & Brown, 1992; Downing, 1996; Yohe et al., 1996; Smithers & Smit, 1997; Smit et al., 1999, all cited in IPCC, 2001). It is also apparent that climate change manifests itself through the underlying elements that define climate variability (Kandji et al., 2006). It is with this understanding that adaptation strategies in Ethiopia were reviewed in this document.

A wide range of adaptation options that are thought to reduce agriculture's vulnerability to climate variability and change in Ethiopia are pursued both at macro- and micro-levels. The government of Ethiopia has taken up the issue of climate change in general and adaptation in particular as a priority agenda in the transformation of the nation's agriculture. At national level (macro-level), the government is pursuing different adaptation strategies that commensurate the national food security. Early warning and response mechanism, safety net programs, natural resource management based adaptation mechanisms, and weather insurance mechanisms are the major adaptive strategies currently pursued by the government.

**Index based weather insurance** enhances the ability of farmers to adapt to climate change by protecting household assets and providing a safety net to agricultural risk, such as crop failure. It increases resilience among farmers by transferring weather risks out of the agricultural community to insurance schemes (Degefa, 2010). For instance, crop insurance is seen as a priority adaptation activity in the Ethiopian NAPA, and may reduce short term vulnerability among socio-economic systems by addressing the risk of serious rainfall fluctuation between years. Since smallholder dry land farmers are highly susceptible to weather-related risks and disasters, crop insurance initiatives can enable them to withstand the loss that they most likely face as a result of seasonal fluctuations or rainfall variability. While crop insurance helps farmers to resolve weather related risks, it fails short of addressing wider climate change issues that alter production systems (Kassu, 2010; ODA, 2008). Since 2006, the Ethiopian government has been committed to shifting from post-disaster relief to risk management (weather insurance is one mechanism) as an approach to emergency response (Hess,

Wiseman and Robertson, 2006). In its initial implementation of the program<sup>1</sup>, the government targeted an estimated 5 million transiently food-insecure people particularly in arid and semi-arid areas, who face food insecurity risk when drought strikes, but are usually able to sustain themselves under normal weather conditions (Balzer & Hess, 2010; Kassu, 2010). Early results show the potential of weather insurance in protecting lives and livelihoods of the farming communities during crises resulting from extreme weather (Kassu, 2010).

Building on the 2006 experience, the government with assistance from WFP, the World Bank and DFID, expanded the concept by designing a comprehensive drought risk management framework that included risk financing. The World Bank piloted the risk financing component of this framework with a US\$25 million contingency grant, which was triggered by WFP's EADI (Ethiopia Agricultural Drought Index) owing to failure of the 2008 short season rains – the Belg. Similarly, WFP and the government, in partnership with the World Bank, introduced the Livelihood, Early Assessment, Protection (LEAP)<sup>2</sup> project (Ibid). The government and donors are currently implementing the program by scaling up to food insecure areas in the country.

Another project-based adaptation mechanism promoted by the government and donors is early warning and response mechanism. Early warning and response mechanism focuses on strengthening the capacity of national and regional offices of the National Meteorological Agency, the Ministry of Agriculture, and the Ministry of Water, Irrigation and Energy. This helps to monitor climate change, generate reliable hydro-meteorological information, and combine the collected facts with environmental and socio-economic information. Resulting data and knowledge is subsequently used for developing information products to improve evidence-based decision-

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<sup>1</sup> It was launched in 2006, with the support of WFP and the World Bank.

<sup>2</sup> LEAP is both an approach and software based on a water balance model. The software allows users to quantify and index the drought and excessive rainfall risk in a particular administrative unit of Ethiopia. LEAP can then be used, for example, to monitor this risk and guide disbursements for a PSNP scale-up. LEAP uses ground and satellite rainfall data to calculate crop production estimates, and subsequently livelihood stress indicators for vulnerable populations who rely on rain-fed agriculture. Based on these, it then estimates the financial magnitude of the livelihood saving interventions that these people will need in the event of a weather shock (Balzer & Hess, 2010).



making for early warning, preparedness, and adaptation responses as well as regular development planning. This form of adaptation is regarded as an example of effective scientific analysis of food security and climate change (USAID, 2012).

However, Alebachew and Aklilu (unknown date) note that the early warning system of the country is narrow in its approach and is biased towards capturing the threats of drought and food insecurity in an emergency situation. Thus, they stress that the system should be reoriented and broadened to capture other emerging threats to livelihoods and ecosystems from climate change induced-hazards which include floods, human, livestock and crop diseases, pests and noxious weeds.

**Safety net program** is also used as adaptation mechanism to improve the food security of the poor while facilitating the engagement of the local communities in improving natural resources management through food/money for work arrangements. The institutional structures of the program heavily rely on the existing local arrangements including community representatives/leaders, disaster prevention committees and local governments. The work includes soil and water conservation structures, planting trees in degraded slopes, and protecting landscapes from excessive use by livestock through 'area enclosure'. There is now evidence that erosion and siltation has been considerably reduced in schemes where extensive soil conservation techniques were carried out. High benefits are also seen in situations where physical measures were accompanied by innovations that bring short-term benefits in terms of fodder, fuel wood, water and other resources to local communities (Tilahun & Amare, 2010).

Micro-level studies, even if few in the field, also documented traditional and contemporary adaptation strategies carried out at farms. Farmers usually undertake adaptive strategies autonomously based on their own perception and experience and/or induced by planned adaptation by various agencies.

Studies carried out independently by Temesgen et al (2009), Abate (2003), the World Bank (2010) and Dejene (2011) show that farmers carry out the following adaptation strategies:

- Using different crop varieties
- Changing planting dates
- Planting trees
- Adoption of drought tolerant and early maturing crops/varieties
- Changing planting dates
- Increased use of soil and water conservation techniques and/or soil erosion prevention programs
- Diversification into non-farming activities
- Water harvesting techniques
- Increased use of irrigation and/or use of irrigation techniques
- Increased use of fertilizer and/or changing fertilizer application
- Changing cropping densities, pesticide application, the pastoral system or the herd composition
- Applying different feed techniques
- Improvement or rehabilitation of terraces
- Temporary or permanent migration
- Home-garden agriculture
- Drawing down on livestock or savings

Both studies by Temesgen et al. (2009) in Blue Nile Basin and Abate (2013) in Blue Nile and Rift Valley Lakes Basins reveal that use of different crop varieties is the most commonly used method in terms of frequency reported by farmers. Temesgen et al. (2009) further reported that the use of irrigation is least practiced among the major adaptation methods identified in the Nile Basin. Whereas application of water harvesting as an adaptation strategy is found to be the least practiced in Abate's (2013) study. Greater use of different crop varieties could be associated with the lower expense and ease of access by farmers and the limited use of irrigation could be attributed to lack of capital and low potential for irrigation (Temesgen et al., 2009). Lack of capital may also apply to the lower practice of water harvesting.

In a study by the World Bank (2010) among farmers and pastoralists, 9 strategies were identified per household and some strategies were regularly adopted jointly or in isolation. Based on factorial analysis, the study grouped the strategies as:

- a. Crop selection, adapting of planting dates, cropping density, and tillage practice;
- b. Adapting fertilizer application, use of irrigation, set up of communal irrigation schemes;
- c. Water harvesting techniques, improved watering sites, communal water harvesting; and
- d. Change from pastoral to sedentary agricultural system

These strategy combinations are related to each other. They either complement each other or are a combination of individual and communal strategies. The study revealed that the first group of strategies is applied regularly. According to this study, the top five strategies adopted contains three communal<sup>3</sup> and two individual strategies. These are:

1. Crop selection (adopt drought tolerant crops; chosen by 78% of the households);
2. Improve or rehabilitate terraces (adopted by 72%);
3. Soil erosion prevention programs (chosen by 69%);
4. Restore or preserve homestead or mountain forests (adopted by 62%) and
5. Adapt planting dates (adopted by 51%).

Although studies list down adaptive strategies implemented by farmers, they fail to measure or clearly show the efficacy of each strategy against climate change. In fact, assessing the effectiveness of climate change adaptation is not an easy task for a number of reasons<sup>4</sup>. But, evaluating the benefit of each adaptation strategy (economic, social and environmental benefits) with the

<sup>3</sup> Strategies that are implemented jointly with other households.

<sup>4</sup> First, adaptation is a relatively new concept to many (notably the development community) although it is a fast moving arena and a number of frameworks to assess the effectiveness of adaptation initiatives are emerging, and there less consensus on ways of measurement. This is the result of little agreement on what constitutes successful or effective adaptation (Spearman and McGray 2011), with various scientists proposing a number of ways to measure adaptation, for example in terms of feasibility, acceptability, effectiveness, efficiency, equity and legitimacy (Yohe & Tol 2002; Adger et al. 2005). Another reason is related to uncertainty of climate change risks. Despite these, many characterize successful adaptation as an improved resilience of those who are vulnerable to climate change, and this can be characterized as either 'bouncing back' to the status quo after a shock or moving beyond this towards achieving longer-term development in light of, or in spite of climate change (Dodman et al. 2009; DFID 2011).



existing frameworks is necessary for scaling up, promoting or redesigning adaptive strategies. Many micro-level studies in Ethiopia simply measure the economic benefit of adaptation as a whole. These studies demonstrated the economic benefit of adaptation to farming households (Mahmud et al., 2008; DiFalco et al., 2011; Abate, 2013).


### **4.3. Barriers and Determinants to Adaptation**

In the above review, adaptation strategies practiced in Ethiopia were explored based on research undertakings in the field. While some studies entirely focus on exploring adaptation strategies, some pay attention also to the factors that affect the propensity of adaptation. In analyzing these factors, the studies generally employed either exploratory (qualitative) analysis or econometric (quantitative) analysis. In rare cases, few studies use the combination of these approaches (Temesgen et al., 2010; Abate, 2013). Understanding these factors helps policy to strengthen propensity and the efficacy of adaptation by addressing and investing in these factors. The discussion first briefs some barriers, and then turns to econometric analysis of the determinants.

### **4.4. Barriers and Determinants to Adaptation**

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Barriers are understood as conditions or factors that reduce the effectiveness of adaptation strategies or any obstacle to reaching an adaptation goal (Moser & Ekstrom, 2010; Huang et al., 2011; IPCC 2007b). Despite research attention in developing many frameworks and approaches to understand the barriers to climate adaptation, there is less comprehensive research to



identify the barriers to adaptation by farmers (Howden et al., 2007; Preston & Stafford-Smith, 2009; Antwi-Agyei et al., 2013). But, trying to understand adaptation in agriculture (overwhelmingly led by small scale farmers) without understanding the barriers highlighted by farmers cannot be viable to inform policy. It is from this perspective that barriers will be discussed briefly in the Ethiopian context.

Agriculture in Ethiopia which is subsistence by nature is mainly constrained by old agricultural practices and structural problems. The emergence of climate change exacerbates these problems and further impedes the adaptive capacity of natural and human systems. Despite these inherited problems in the agricultural system, farmers in Ethiopia often face a wide range of constraints in adapting to climate change. Generally the literature indicates that technology, biophysical resources (e.g. availability of land, water), finance, information, infrastructure, institutions and political will influence adaptation at all levels. Farm level studies in the context of Ethiopia support this general view. A study by Temesgen et al (2009) indicate that lack of climate information and finance, shortage of labor and land, and poor potential for irrigation were reported by farmers in Blue Nile Basin as major barriers in their adaptive efforts. Similarly, Abate's (2013) study in the Blue Nile and Rift Valley Lakes Basin shows that farmers are constrained by a range of barriers with the most important including lack of financial capacity, lack of awareness and technical knowledge, and lack of suitable crops/species (drought resistant) and improved seed.

It is fact that adaptation requires financial resources to purchase inputs and lacking these resources implies less to spend on adaptation. Lack of information has two forms: lack of information weather (local climate) and adaptation methods. In developing countries like Ethiopia, there is lack information on local climate due to shortage of weather stations and even in the availability of these stations, the culture of disseminating information to users and using the information for decision making among farmers is not established well.

Lack of awareness and technical knowledge on adaptation methods is another impediment that could reflect lack of information outlet, technical personnel and guidance on adaptation options. In this regard, the government has

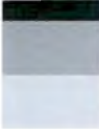


deployed three agricultural development agents in each farmer villages. Each of the agricultural development agents is either specialized in crop, livestock or natural resources management so as to deliver extension services to farmers as part and parcel of the government's policy to boost agricultural production and productivity. Abate (2013) explains that even if farmers acknowledge the importance of the agents, farmers blame the agents having only equipped with words that lack tangible and transferable practical skills. On the contrary, these agents assert that they educate and advise farmers but complain about farmers' reluctance in putting the advice into effect (practice). One problem may be related to development agents' dictation of farmers to implement agricultural packages and prescriptions channelized through top-down approach which might not be compatible with specificities of agroecosystems. The other may be linked with what the agents assert as lack of timely supply and higher price of agricultural inputs that might hamper farmers' effort in implementing adaptation and productive technologies that the agents recommend. Farmers' assertion of lack of improved seeds and suitable crops/species (drought resistant) as one of the obstacles in adaptation could also be linked with untimely supply and unaffordable price of these inputs. Even in some cases, counterfeit seeds are provided by merchants and a number of farmers have already lost due to failed harvests (Abate, 2013).

In fact, policy-driven adaptation to climate change and variability is yet an emerging issue and the development agents might lack theoretical and practical skills in adaptation science. On top of this, introducing new forms of adaptation could be difficult given the country's low levels of agricultural research and development (R& D). Consequently, most of the adaptation methods applied by farmers are traditional ones and the agents are mostly limited to advise farmers to use these strategies through diversification and intensification (Ibid).

Other problems such as shortage of land and labor are also reported to be barriers to adaptation. Land is obviously crucial to implement and sometimes test the effectiveness of adaptive strategies before scaling up in the farms. Farmers in Ethiopia are largely confined to small fractions of land holdings (an average of 1.22 hectares per household (CSA, 2012)), and thus land size is not only a constraint in adaptation but also regarded as a poverty trap among





agricultural households in rural Africa (Jayne et al., 2003). In a general, these all problems could be linked with poverty and lack of agricultural research and development (R & D) that helps to design and introduce new adaptive strategies that could be effective in the local context.

Besides these farm level barriers, Simane & Zaitchik (2014) in their study of community based adaptation (CBA) in the Blue Nile Highlands of Ethiopia identified a number of barriers. They classify some of the barriers as technical and these include inadequate community members' training and farmer capacity, and lack of understanding of adaptation process, information and impact assessments. Others are political and include inter-departmental conflicts, inadequacy of local government's commitment and community participation, issues of 'territoriality', lack of guiding principles and limited understanding at Wereda and Kebele levels. Some other barriers come under culture and include reluctance to overstep existing activities and traditions and a tendency not to view landscape level issues as community problems. Based on participatory evaluation of CBA, they concluded that many of these barriers are attributed to the decision to use conservation of natural resources as the primary framework for CBA activities.

#### **4.4.1. Determinants of adaptation**

By nature, adaptation is a dynamic phenomenon that requires multidimensional processes and a set of resources. It is generally acknowledged that adaptation at national level is the reflection of the socioeconomic development of a country. At local level, adaptation is influenced by such factors as managerial ability, finance, technology, information, infrastructure, political influence, kinship networks, institutional environment within which adaptation occurs (Smit & Wandel, 2006). Since adaptation is actually occurring at local levels, the interest of adaptation research in Ethiopia focused at studying enabling factors at this level.

Econometric analysis by Mahmud et al (2008), Temesgen et al. (2011), Di Falco et al. (2011) and Abate (2013) show that propensity of adaptation among farmers is significantly affected by such factors as sex, household size, livestock ownership, education level, social capital, access to credit, information on climate and extension services (both formal and farmer-to-

farmer). Male-headed households are more likely to implement adaptation strategies as compared to their female-headed counterparts. The justification might go with rural women's less control over resources, technology, extension services and information which are considered to play an important role on adaptation process (Meinzen-Dick et al., 2010; Nabikolo et al., 2012).


Similarly, large household size is found to be related with increased likelihood of adaptation. This might be because large family size is probably associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks especially during peak seasons (Croppenstedt et al. 2003).

Provision of climate information plays an important role by keeping farmers up to date and alerted on the severity of the threat so that it helps them to decide on adaptation. For instance, if farmers get timely seasonal information on weather conditions, they can easily decide whether there is a need for changing planting dates given credibility of the source of information. Extension services provide an important source of information and education, for instance, on changing crops and specific soil conservation measures that improve productivity (Di Falco et al., 2011). Likewise, access to credit relaxes financial constraints of farmers to purchase inputs, invest on productive strategies and meet transaction costs related with adaptation (Nhemachena & Hassan, 2007).

The other surprising result among these studies is the role of social capital<sup>5</sup> being a negative factor for adaptive behavior. In Abate's (2013) study among farmers in Blue Nile and Central Rift Valley Basins, increased membership in social organizations decreases the probability of adaptive behavior among farmers. Through networks and social interactions with in social organizations, members can have more access to resources such as information, risk management skills and other transferable knowledge which could be used for decision making in adaptation efforts. Despite this, it is paradoxical to notice membership in social organizations affecting adaptive behavior negatively and significantly. This result is surprising given the importance of social organizations (as a form of social capital) in enhancing

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<sup>5</sup> Sometimes comparisons are difficult as measurement of the variable is different in many studies.



adaptive capacities of individuals (Adger, 2001; Adger, 2003; Halsnæs & Verhagen, 2007; Pelling, 2011). It might be less clear why membership in social organizations negatively influence adaptive behavior. Nevertheless, most probable reason could be postulated. Members in social organizations might be spending a lot of time in non-productive activities, such as political networking and discussions.

## **4.5. Adaptation options**

The science of climate change and its impact on natural and human systems in general and agriculture in particular is uncertain. This is not only because of uncertainties in climate projections, but also because of the lack of thorough understanding of key processes in climate change responses and the efficacy of the responses in the face of uncertain climate. Despite this universal drawback, a wide range of no and low regret adaptation options that are thought to reduce agriculture's vulnerability to climate change in Ethiopia are

already proposed based on lessons learned in the past and community-based ecosystem adaptation practices. Even if very scanty, there is also an attempt to recommend adaptation options based on climate change scenarios.

### **4.5.1. Agroecosystem-based Adaptation**

Agroecosystem based adaptation (also termed as community-based ecosystem adaptation) is brought here not to precisely propose or list down specific adaptation options, rather to present a framework that helps to develop ecosystem-based adaptive strategies. Based on a five year study of climate vulnerability and adaptation strategies in the Upper Blue Nile highlands, Simane et.al (2012) concluded that a community by ecosystem-based approach has significant potential for building climate resilience in communities across the region. They argue that localities have diverse biophysical conditions, socio-economic factors and agroecosystems. This physical diversity and accompanying socio-economic and agricultural contrasts demand diverse strategies for enhanced climate resilience and adaptation to climate change. Hence, agroecosystem-based adaptation (community-based ecosystem approach) is the most appropriate unit for defining adaptation strategies among primary subsistence agriculture communities and gradually builds climate resilience.



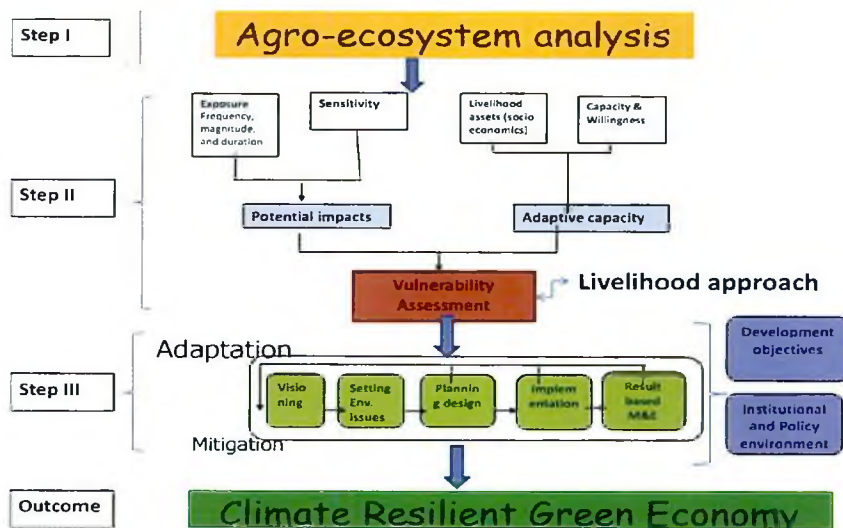
#### 4.5.1.1. A Framework for building Resilience to climate change

Based on the above argument, Simane et al (2012) developed a framework (Fig. 13) for building resilience to climate change at a local level in the Blue Nile/Abay Highlands (Choke Mountain) and beyond. The framework places both human and natural systems at the center of analysis when considering vulnerability to climate change. The guiding principle is that impacts and vulnerabilities must be evaluated at the community by ecosystem level in order to generate science-based information for mitigation and adaptation. This information can be used to enhance coping capacity to climate change and subsequently to promote a carbon neutral and climate resilient economy in Ethiopia.

The framework begins with classification and analysis of major agro-ecosystems on the basis of ecology, soil, and farming systems. This provides the environmental context for climate risks and climate resilience. Next, potential impacts and the vulnerability of communities and sub-ecosystems within each agro-ecosystem must be evaluated<sup>6</sup>. The approach places people, particularly rural poor people, the resources and livelihood assets (human , natural, financial, physical and social resources) that they have access to and use. The extent of their access to these assets is strongly influenced by their vulnerability context, which takes account of trends, shocks and seasonality. Access is also influenced by the prevailing social, institutional and political environment, which affects the ways in which people combine and use their assets to achieve their goals. These are their livelihood strategies. Adaptive capacity of society is used to describe the livelihood assets the communities have to plan, prepare for, facilitate and implement adaptation measures.

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<sup>6</sup> They also detailed methodologies of impact analysis in their paper. They employed the Sustainable Livelihood Approach for vulnerability assessment.



**Figure 13.** A conceptual framework for building resilience: Community by Ecosystem Based Approach.

Source: Simane et al., 2012

The third step of the framework posits that building climate resilience is possible through appropriate adaptation and mitigation options designed with consideration for local adaptive capacity and agro-ecosystem. Adaptation, for both ecosystems and human systems, is a process that requires the engagement of a wide range of stakeholders at multiple levels and in multiple sectors. It requires analysis of current exposure to climate shocks and stresses and model-based projections of future climate impacts. It demands an understanding of the existing vulnerability of individuals, households, and communities. With this information, adaptation strategies can be designed and implemented. Monitoring and evaluating the effectiveness of activities, as well as sharing knowledge and lessons learnt, are critical components of the process. The framework also recognizes that policies and institutions play a critical role in supporting or constraining people's capacity to adapt to climate change.

#### 4.5.1.2. Realizing climate resilience through climate innovation platforms

The concept of community-based ecosystem adaptation in rural areas of Ethiopia encompasses a wide range of strategies at local and landscape scales, enabling communities to address climate change in an effective way. It is envisioned that ecosystem-based adaptation interventions will be developed and implemented by community-based innovation platforms, and that they will be a component of a broader adaptation strategy that includes education, training, awareness rising, and the development of early warning systems and technology measures as required.

As described above, based on 5 years of project and research experience (with 21 targeted community-based adaptation development projects), Simane et al. (2012) applied their framework to develop community based adaptation strategies through innovation platforms (IPs). The IP model follows a systems approach that considers the entire agricultural production system, relevant value-chains, physical environment, and the interactions between them. Further, the IP model approaches community-based adaptation as a process that involves community empowerment, development and application of appropriate technologies and practices, and the establishment of vibrant market connectivity. This process requires time and investment, and it also requires deliberate engagement with communities in a manner that respects traditions but is, when necessary, freed from prevailing power dynamics as much as possible. IP sessions that engage only women from the community, for example, are found to yield insight on adaptation priorities and innovation opportunities that are not emphasized in mixed-gender settings.

The IP model centered on individual households within target micro-watersheds, with a focus on empowering vulnerable people with the knowledge, skills and resources they need to take action on the climate change adaptation strategies appropriate for their lives and livelihoods. In all projects, preservation of the natural resource base was taken as an entry point for planning adaptive actions. The projects are rooted in a participatory, comprehensive analysis of the biophysical vulnerability that allows different groups - such as poor women or other marginalized people in the community - to identify targeted strategies based on their specific needs and priorities.





Figure 14. The four pillars of innovation platforms

Source: Simane et al., 2012

While much has been learned through these projects, the sustainability of projects that take the natural resource base as an entry point has come into question. Interventions that are effective during the active project period, when external investments in adaptation capacity are made available, often fail to establish the link to markets that is required to sustain efforts after the project comes to a close. Based on this experience, participants have concluded that markets are a more appropriate entry and exit point for future resilience building efforts. This recognition has yielded a model that centers on the establishment and implementation of community-based IP, devoted to achieving a climate resilient green economy through dissemination and uptake of proven technologies and practices (Fig. 14). As learned at Choke Mountain, an effective partnership is a necessary precondition to market-based technology transfer. The IP model also acknowledges that it is necessary to establish an enabling policy environment to make the partnership arrangement work legally.

Inherent to the IP concept is the fact that innovation is driven by broad stakeholder involvement: farmers and their organizations, representatives


of (national and international) research and extension, the private sector (input and output markets, food processing, transport, rural credit), local government (policy, subsidies, and rural credit), NGOs and others. These stakeholders must begin by analyzing challenges and limitations to livelihood improvement at the household and community level and by defining priority issues to address. Then, collectively, participants in an IP will identify and rigorously test proposed solutions. Finally, the IP is also responsible for implementing promising solutions, monitoring the implementation, and addressing problems or new challenges that arise in the course of time.

Experience at Choke Mountain has provided a strong foundation for ecosystem based adaptation, but it will be critical to maintain active analysis and a flexible approach to implementation as the IP experiment moves forward. For scaling up the IP model, major activities focus on transforming the agriculture sector based on agroecosystem and vulnerability assessment through:

- a. Establishing voluntary local institutions (IP);
- b. Accelerating access to technology and investment;
- c. Improving market mechanisms for climate resilient and sustainable products and practices;
- d. Defining environmental management as a community-level issue; and
- e. Empowering community members to address governance matters at the local level, and empowering communities to identify broader governance needs.

#### **4.5.2. No/low regret adaptation options**

A wide range of no and low regret adaptation options that are thought to reduce agriculture's vulnerability to climate change in Ethiopia are proposed by several researchers and organizations. These adaptation options were compiled and detailed mainly by National Adaptation Program of Action (NAPA), the Ethiopian Program of Adaptation to Climate Change (EPACC, which updated NAPA), and Agriculture Sector Programme of Plan on Adaptation to Climate Change (MOA). The first two (NAPA and EPACC) dealt with adaptation options in other sectors as well. Whereas, the MOA's Agriculture Sector



Programme of Plan on Adaptation to Climate Change (2011) lists down no and low regret adaptation options entirely focusing on the agricultural sector.

No and low regret adaptation options strengthen resilience to current variability and accommodate additional variability, emerging climate trends and future climate change. Most of these strategies are existing practices or part of existing policies, and many of them have multiple benefits by increasing productivity and natural resource protection. The MOA (2011) asserts that most of these adaptation measures in the agriculture sector can provide net benefits regardless of climate change and in real terms are no regrets or low regrets measures which are already rationalized under current climate. This is to say that precise climate change projections may not be necessary to validate these measures. Therefore, the agriculture sector is believed to have good opportunities to build its adaptive capacity by capitalizing on existing good practices and taking corrective measures on constraints and gaps realized. Table 13 below shows the measures along with the potential results achieved so far and/or expected of them.



Table 13. Portfolio of good practices/technologies

Portfolio of Good Practices/ Technologies	Achieved/Potential Results/ Impacts
Soil and water conservation	soil erosion avoided or minimized infiltration improved, soil moisture retained runoff controlled and wastage of available water reduced soil fertility increased vegetation cover increased
Sustainable land management	primary production increased (vegetation cover, crops) rivers, lakes, ground water levels regulated water discharge from highland to lowland areas regulated provisions of food, fodder, fuel wood, and freshwater improved soil carbon sequestration increased
Water harvesting and moisture conservation	moisture stress supplemented and crop productivity increased survival of trees increased grassland and rangeland rehabilitated flood water management improved water supply for domestic uses increased
Small scale irrigation development	rural food security promoted, poverty alleviated adaptation to climate change improved household alternative income generated and increased small-scale employment (labor) increased

Land rights certification	<p>positive economic impact and improved tenure security</p> <p>improved investment on land</p> <p>increased supply of land to rental market</p>
Participatory forest management	<p>increased awareness on benefits and services of forest</p> <p>improved community institutional capacity to manage forests</p> <p>encouraged social equity , gender and minority rights</p> <p>provided local community with significant alternative income such as honey, spices, bamboo, etc.</p>
Agroforestry / Homestead fruit production/ small-scale plantations	<p>increased household income</p> <p>alternative food supply</p> <p>fuel wood and construction material supply</p> <p>increased soil fertility</p>
Sustainable management of dryland and sub-humid/ lowland forests	<p>source of household income and generate hard currency</p> <p>supply of food products and additives</p> <p>source of bio/organic chemicals</p> <p>supply of feed for livestock</p>
Protection and management of forest fires	<p>adequate feed supply</p> <p>livestock production improved</p> <p>income from livestock production increased</p> <p>ecosystem services of rangelands promoted</p>
Biodiversity conservation and sustainable utilization	<p>native ecosystems restored and maintained</p> <p>ecosystem services enhanced</p> <p>endangered species protected</p>

Provision of practical and better agricultural extension	<p>crop disease, pest, weed protected          animal disease protected and veterinary services provided          crop productivity increased          livestock productivity increased          agricultural production diversified          agricultural investment promoted          income and GDP uplifted</p>
Public welfare programs	<p>food security achieved          house hold assets built up          poor and drought affected people social security attained          natural resources preserved and their multipurpose functions enhanced</p>
Early warning system	<p>disasters from floods, drought, fire etc minimized or controlled          deaths of people from disasters prevented          necessary information obtained to make necessary coping steps before disasters happen</p>
Voluntary resettlement	<p>potential and underutilized lands developed          many people have resolved their land scarcity due to degradation and food shortage          food security achieved</p>



Provision of agricultural research and extension	new agricultural and natural resource technologies adopted gaps and constraints in existing practices resolved measures improving agricultural productivity introduced improved crop and animal varieties introduced seedlings survival techniques improved economic contribution of timber and non-timber forest products enhanced
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Source: MOA (2011)

The MOA (2011) believes that these strategies can be appropriate response measures to adapt to climate change by readjusting certain factors to fit to changing climate. But, it stresses for the need to revitalize and maximize the benefits of these measures by improving and integrating steps of climate proofing in order to successfully achieve a full-fledged climate change adaptation in agriculture sector. Besides, it is crucial to augment the existing good practices in a way that integrate the challenges of climate change properly. To this effect, MOA (2011) suggests some strategies and measures for the success of adaptation in the agriculture sector which include climate monitoring and forecasting; disaster and risk management programs; food security programs; social welfare programs; integrated pest and disease management; efficient central-local coordination and harmonization; robust institutional capacity at the local level; and incorporation and mainstreaming of climate change adaptation into development policies.

Besides the Ministry of Agriculture, Regional States have also identified many adaptation options. A summary of these adaptation strategies is shown below in Table 14.

**Table 14.** Summary of the Regional Adaptation Plan Priorities

	Addis Ababa	Afar	Amhara	Benishangul-G.	Diredawa	Gambella	Harar	Oromiya	Somali	SNNP	Tigray
Agriculture - Cropping practices	X	X	X	X	X	X	X	X	X	X	X
Change/diversify crops and varieties grown		X	X		X	X	X	X	X	X	X
Crop research and development	X		X	X	X	X	X	X		X	X
Maintenance of traditional varieties & diversity					X			X		X	X
Increase/improve inputs (labour, fertilizer, etc)		X	X	X	X	X	X	X	X	X	X
Agriculture - Livestock practices	X	X	X	X	X	X	X	X	X	X	X
Modify livestock practices	X	X	X	X	X	X	X	X	X	X	X
Animal health	X	X	X	X	X	X		X	X	X	X
Breeding/herd diversity		X	X	X	X	X	X	X	X	X	X
Feed/fodder/forage/water	X	X	X	X	X	X	X	X	X	X	X
Sustainable land management	X	X	X	X	X	X	X	X	X	X	X
Soil/water management	X	X	X	X	X	X	X	X	X	X	X
Conservation/rehabilitation/promotion biodiversity	X	X	X	X	X	X	X	X	X	X	X
Land and watershed management/planning	X	X	X	X	X	X		X	X	X	X
Forestry	X	X	X	X	X	X	X	X	X	X	X
Improved forest management practices	X	X	X	X	X	X	X	X	X	X	X
Reforestation/afforestation, climate-specific species	X	X	X	X	X	X	X	X	X	X	X
Agro-forestry			X	X	X	X		X		X	X
Seed storage & nurseries	X		X	X	X				X	X	X
Commercialisation/diversification of forest products				X	X					X	X



Water	X	X	X	X	X	X	X	X	X	X	X
Water resource development/ management	X	X	X	X	X	X	X	X	X	X	X
Irrigation/improved irrigation	X	X	X	X	X	X	X	X	X	X	X
Flood risk management	X	X	X	X	X	X	X	X	X	X	X
Water efficiency/allocation	X	X	X		X	X	X	X	X	X	X
Knowledge, information, capacity building	X	X	X	X	X	X	X	X	X	X	X
Climate research, meteorology and EWS	X	X	X	X	X	X	X	X	X	X	X
Community/stakeholder participation	X	X	X	X	X	X	X	X	X	X	X
Knowledge building, education/ extension	X	X	X	X	X	X	X	X	X	X	X
Institutions	X	X	X	X	X	X	X	X	X	X	X
Land/property rights	X		X	X	X			X	X	X	
Regulation, monitoring and enforcement	X		X		X		X	X	X	X	
Strengthen institutions traditional/community	X	X	X	X	X	X	X	X	X	X	X
Livelihood development and diversification	X	X		X	X	X	X	X	X	X	X
Access to financial services: credit & insurance	X	X	X		X	X	X	X	X	X	X
Improved transport & communications network	X	X	X	X	X	X		X	X	X	X
Improve marketing/access to markets	X	X	X	X	X	X	X	X	X	X	X
Disaster Risk Management	X	X	X		X		X	X	X	X	X
Disaster planning & prevention	X	X	X		X		X	X	X	X	X
Movement/resettlement/ migration/transhumance	X				X			X	X	X	X
Safety net/humanitarian assistance							X	X	X	X	X
Conflict mitigation/resolution		X	X	X	X	X		X	X	X	X

Source: MOA (2011)



On the other hand, the country's Climate Resilience Strategy as part of building Climate Resilient Green Economy identified about 40 promising options through a long process of review and evaluation. It grouped these options into 3 strategic areas:

- Strategic area 1: Capacity building and cross-cutting activities that establish the capacity for managing change and sectoral resilience.
- Strategic area 2: Building on existing good practice in the agricultural sector (no-regret and robust options).
- Strategic area 3: Protecting the most vulnerable (aligning to the DRM FSS/Disaster Risk Management and Food Security Sector/ sub sector of the Ministry of Agriculture).

Within each of these strategic areas, specific activities (sub-sectoral level) have been identified, that comprise broad themes. Table 15 shows the list of the options.

**Table 15.** List of promising resilience options

<b>Strategy Area 1. Establish capacity for managing change and sectoral resilience</b>	
Sub-sectors	
	Key Themes
Capacity building and institutional coordination (staff, training)	
	Climate information, research and enhanced co-ordination
	Institutional strengthening and building
Information and awareness (climate, agro-met services, R&D)	
	Meteorological and agro-metrological data
	Agricultural research and development
	Enhanced extension services
<b>Strategy Area 2. Build on existing good practice (no-regret and robust options)</b>	
Sub-sectors	
	Key Themes
Crop and water management on-farm (e.g. crop switching, smallholder irrigation)	
	Crop switching and new varieties
	Fertiliser use
	Farm management and technology
	Pests and disease (including post-harvest losses)
	Irrigation

	Water infrastructure, allocation and transfers
Livestock	
	General animal and value chain improvements
	Herd diversification
	Breeding programmes
	Improved animal health
	Fodder and feed improvement and resilience
Value chain and market development (i.e. commercial sector and exports (coffee, sugar), roads)	
	Coffee (Monitoring (yield, quality, pests), capacity building, new varieties, shade trees, conservation, new plantations.)
	Irrigated sugar plantations (irrigation efficiency, changes to practice, integrated basin management, upstream catchment rehabilitation, climate risk screening).
	Roads (new roads, paving, design standards)
Sustainable agriculture and land management (SWC, SLM, climate smart)	
	Conservation agriculture (zero or low tillage, cover crops, crop residues)
	Soil and water conservation (SWC) structures (bunds, trees, grass strips, contour levelling, terraces, shade trees, waterways).
	SWC cover crops
	SWC water harvesting (tied ridges, RWH, local structures).
	Soil management
	Agroforestry
Forestry, conservation and biodiversity (including ecosystem based adaptation)	
	Using forests for adaptation
	Resilience measures for forests
	Conservation and rehabilitation
	Promoting biodiversity in agriculture
	Payment of ecosystem services
<b>Strategy Area 3. Protect the most vulnerable</b>	
Sub-sectors	
	Key Themes

Disaster Risk Reduction	
	Early warning systems
	Disaster risk management planning
	Insurance
	Structural protection
Social protection for high priority groups including women and children	
	Safety nets
	Asset creation and protection
	Access to credit
	Livelihood diversification
	Resettlement/migration

Source: FDRE, 2011)

Another study carried out by the World Bank (2010) among households in rural Ethiopia identifies climate change adaptation options in geographic and social zones. Among these, the strategies directly related to agriculture in the central, northern and western highlands are listed as follows:


- Land conservation and biodiversity
- Access to agricultural technology, financing and markets
- Income diversification and agro-industry
- Irrigation and water harvesting

#### 4.5.3. Adaptation options based on climate change scenarios

There is nearly negligible research output on adaptation options developed based on climate change scenarios of Ethiopia. The most important line of research in this regard is World Bank's (2010) research that proposed adaptation options based on four scenarios<sup>7</sup> of climate change (Wet1, Dry1,

<sup>7</sup> The four climate change scenarios, Wet1, Dry1, Wet2 and Dry2, are intended to capture the range of possible variability in Ethiopia. The scenarios were selected to span the range of possible climatic change as measured by the Climate Moisture Index (CMI). The CMI is an aggregate measure of annual water availability. It provides for an integrated measure of the impact of climate change on soil moisture and runoff from changes in both temperature and precipitation. Wet1 and Dry are the wettest and driest scenarios (respectively) measuring the changes in CMI over all the land area of the globe, whereas Wet2 and Dry2 represent the wettest and driest scenarios (respectively) in the specific case of Ethiopian land area. Wet1 which is derived from ncar\_ccsm3\_0 global circulation model represents global wet scenario; Dry1,





Wet2 and Dry2) derived from four general circulation models (GCMs). Based on these scenarios, the Bank proposes increasing irrigated cropland and investment in agriculture research and development (R & D) as the two pillars of national adaptation strategies in agriculture.

These two pillars of adaptation strategies are meant to capture key aspects of a strategy capable of tackling the essential features of the climate of the future—that is, an increase in temperature, which is common to all scenarios—and changes in precipitation patterns (in varying directions and magnitudes, depending on the climate change scenarios). Under all scenarios, temperature increases, with negative impacts on crops yields. Investment in R&D is thus intended to maintain technology-induced productivity growth in the agricultural sector at the base (no-climate-change rate) by developing new crop varieties optimized for the changed climate. On the other hand, expansion of irrigation is proposed not only in dry scenarios but also in wet scenarios to match the magnitude of climate-change induced irrigation deficit. As warming increases, crops demand an amount of water greater than the increases in precipitation during the growing season. Changes in precipitation intensity and seasonality call for increased installation of drainage systems, especially in wet scenarios.

The World Bank (2010) also proposes adaptation strategies at community level developed based on local participatory scenario development (PSD) workshops. These adaptation strategies include soil and forest rehabilitation, irrigation and water harvesting, improved agricultural techniques and drought-resistant varieties, education, and land use rights for pastoralists as adaptation preferences.

#### **4.5.4. Adaptation in the crop sector**

In the preceding section, adaptation options in the crop sector are stated as part of the general adaptation options in the agricultural sector. This subsection briefly discusses adaptation strategies in the crop sector. There

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derived from *csiro\_mk3\_0*, represents a global dry scenario; *Wet2*, derived from *ncar\_pcm1*, is a scenario depicting Ethiopia wet; and *Dry2*, on the contrary represents Ethiopia being dry and is derived from *ipsl\_cm4* GCM. Temperature is expected to increase in all of the scenarios and there will be changes in precipitation patterns (in varying directions and magnitudes, depending on the climate change scenarios).

are a number of existing agricultural techniques that have been practiced at farm levels. Enhancement of the practice of these techniques coupled with the supplement of new techniques can create viable options for adaptation. As indicated in the CRGE (2011), adaptation in the crop sector includes the following options.


#### **4.5.4.1 Crop switching and new varieties**

It is well recognised that there are a large number of farm level responses around the choice of crops, particularly in highly vulnerable areas such as the drylands. Besides these responses, an obvious response to changing climate conditions requires introduction of different varieties such adoption of heat resistant species, drought tolerant varieties, disease resistant varieties, early maturing species, and crops that use water efficiently, that maximize biomass production and comparative advantage. These crop trait-based adaptation techniques coupled with appropriate agronomic management practice are key areas that are recommended for adaptation. In this regard, some promising research activities undertaken by the National Agricultural Research Systems (NARS) and the CGIAR (Consultative Group for International of Agricultural Research) could help to facilitate the adaptation process at the right time.

As clearly stated in the CRGE (2011), Ethiopia has a rich biodiversity with highly valuable genetic resources with tolerance to shocks of temperature extremes, drought, flooding, pests and diseases. Preservation of this of genetic resources is fundamental in developing resilience of plants and animals to shocks, in improving the efficient use of resources, in shortening production cycles and in generating higher yields and improving market access. The role of farmers in preserving local crops and seeds is important, and there is a need to support farmer conservation and maintenance of crop diversity through contribution to benefit sharing mechanisms.

#### **4.5.4.2 Fertilizer use**

One of main responses identified in the climate change literature from crop models is the use of additional fertiliser to increase productivity (or more efficient use of fertilisers) to compensate for the yield losses from climate change. As far as fertilizer is used efficiently, it remains to be one of the options for adaptation. But, the Ethiopian government advocates organic



fertilizer as part of its commitment to the CRGE strategy which envisages carbon zero economy.

#### **4.5.4.3. Farm management and technology**

General improvements in agronomic management practice and technology can improve agricultural production and help address climate change, ranging from use of labour, diversified crop rotation or mixed farming through to technology and mechanisation.

#### **4.5.4.3. Pests and disease (including post-harvest losses)**

There are high existing losses from pests and disease in Ethiopia and addressing these offers the potential to improve current productivity as well as reducing the potential impacts from increased or new risks from climate change. This leads to a set of options around monitoring, surveillance and responses to the spread and development of plant disease, as well as more resilient varieties. A related aspect is the high level of post-harvest losses currently; again, actions to reduce current losses increase general resilience and management activities or improved storage facilities will help build resilience.

#### **4.5.4.5. Irrigation**

Irrigation is one of the main adaptation options identified and quantified in modelling assessments of climate change. Studies in Ethiopia also report irrigation having a doubling effect on net gross margin for farmers. Due to this and other socioeconomic reasons, the government (Agricultural Growth Project) has focused on the development of small-scale irrigation so as to increase productivity and reduce the impacts of climatic variability and change. A variety of technical and management options existing for irrigation. There are also the potential for medium- or large-scale irrigation projects, groundwater projects, as well as more traditional or local scale structure.

#### **4.5.4.6. Soil and water conservation (SWC)**

Ethiopia loses an estimated two billion metric tons of soil to erosion each year, leading to an annual loss of productivity of 2 - 3 % of agricultural GDP each year (Yesuf et al., 2005). Besides lessening such effects of erosion, soil



and water conservation measures could help to reduce the impacts of climate change by controlling runoff and maintaining soil moisture. SWC measures include:

- a. Soil and water conservation structures, which include bunds, trees, grass strips, contour leveling, and terraces (stone, bench, contour), shade trees and waterways.
- b. There are also additional SWC options in the form of cover crops (planted post-harvest or intercropped), intercrops, improved fallows (legumes) and alley crops, which can improve soil and water conservation characteristics by keeping cropland covered during the entire year (reducing erosion and enhancing moisture), and for some options (legumes) increasing soil fertility.

There are also a wide number of water conservation measures (in addition to the soil and water conservation measures above). Examples include tied ridges (in situ water harvesting), small scale water-harvesting structures such as dams and ponds.


#### **4.5.4.7. Soil Conservation and Water use efficiency and allocation**

A further set of potential resilience measures involve improving the efficiency of water storage, transfers and delivery (a no regret option) and also considering allocation rules or market based mechanisms.

Climate change may lead to an increased frequency of constraints on natural resource availability; for example, through increased droughts or soil erosion. Adaptive capacity can be improved by improving the mechanisms available to manage this scarcity. Water trading has been shown to be beneficial in times of drought in developed countries (Australian Government National Water Commission, 2010; Connell-Buck et al 2011; Sivakumar et al., 2011). These lessons could be adapted to the Ethiopian context based the actual conditions in the respective localities.

#### **4.5.5. Adaptation in the livestock sector**

Livestock keeper have traditionally adapted to various environmental and climatic changes by building on their in-depth indigenous knowledge of the environment in which they live. However, the increasing human



population, urbanization and land degradation have rendered some of those coping mechanisms ineffective (Sidahmed, 2008). Moreover, changes brought about by global warming are likely to happen at such a speed that they will exceed the capacity of spontaneous adaptation of both human communities and livestock species. These a well-organized and knowledge-based national strategy is required to combat the effect of climate change on livestock production. Different actions or approaches are recommended to combat the effect of climate change on livestock production in mixed crop-livestock system such as the use of adapted farm animal genetic resources, improve feed and feeding system, herd diversification and production system adjustment or intensification (World Bank, 2011; FAO, 2008; CRGE, 2011).

#### **4.5.5.1. Using adapted farm animal genetic resources**

Ethiopia has the largest livestock population in Africa with divers breeds (includes 27, 9, 12, 4 breed of cattle, sheep, goat and camel respectively. Cattle play the most important role in the farming economy followed by sheep and goats. The indigenous livestock population of Ethiopia perform best in their natural environment have the potential capacity to cope with the harsh environmental conditions of the country. They often have special adaptive traits for disease resistance, heat tolerance and ability to utilize poor quality feed which they have acquired through natural selection over hundreds of generations.

Selection for adaptation and production traits among indigenous livestock will increase the ability of the animal to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann, 2008). Identifying indigenous livestock breeds that have the capacity to adapt to existing and future climate change stress (Temperature, feed and diseases) and improving through selection will increase the adaptive capacity of the animal and decrease the vulnerability to climate change and variability. For example in tsetse infested area enhancing the trypano-tolerant ability of indigenous cattle breed through selection for trypano-tolerant trait will improve the ability of the animal to survive and produce under the disease challenge.

#### 4.5.5.2. Feed and feed system development

To minimize the effect of climate change on feed and animal productivity different feeding strategies are recommended such as rotational grazing, reseed pasturelands, crop residues treatment with urea, forage development; efficient feed production techniques such as silage and urea molasses block preparation. These techniques will increase the quality of available feed, improve digestibility, rate of degradation of fibrous feed by the animal and increase feed intake. Under climate change (increase in temperature) the structural constituents of plant materials such as lignin, cellulose and hemicellulose is reported to increase (Climate resilience strategy of Ethiopia draft document, 2014). Different technology and practices are in use to remove these plant cell structural constituents such as treatment of crop residue with alkalis to improve digestibility is a well-researched and established technique. Feeding treated straw as compared to untreated straw considerably improve ruminant productivity (Sundstol and Owen 1984). Simple technique based on ensiling the wet straw with three to four per cent urea are well established and could be applied under village condition (ILCA, 1994) to improve nutrient available to the animal. Enhancing the utilization of fibrous feed material through the use of effective microbial technology (EM) is other technological options to be adapted (Getu et al., 2013).

Leguminous forage and the use of multipurpose (*Leucaena*; *Gliricidia*) tree in mixed farming system is an important strategy to overcome the shortage of feed especially in dry period (ILCA, 1994).

#### 4.5.5.3. Production system adjustment

Changes in livestock production practices such as intensification and/or integration of pasture management, introducing mixed livestock farming systems such as feedlot fattening, and improved pasture grazing are some of production adjustment strategy recommended for climate change adaptation in mixed crop-livestock system (FAO, 2008; Thornton, et al., 2008; Sidahmed, 2008).

According to FOA, there are three distinct entry points that may lead to a better way of coping with the negative consequences of climate change and associated drivers of disease, pest dynamics and the overall health status of



animals. These are;

- Preventive veterinary medicine: As has been indicated in FAO Emergency Prevention System (EMPRES), early warning, early detection, and early response have been a key to the prevention and control of both old and new pests and diseases in animal and crop production. Livestock grazing in the open grazing land exposed to multiple vector borne diseases including new diseases. Production of quality vaccines of major economic important diseases of livestock is required to confront a vast array of old and new diseases in Ethiopia.
- Adjustment of animal husbandry: Improvement in sanitation, hygiene or bio-security may conveniently take a whole-of-society approach. The management of animal genetic resources, feeding practices, housing and bio-containment together plays a key role in the maintenance of robust, healthy and productive animals.
- Social resilience: Empowering the community regarding health protection also stated as the key strategy. Animal health system and infrastructures are weakest in rural areas where livestock production is the most prominent; self-help options supported by community animal health outreach are rapidly gaining in importance (FAO, 2008) and can be used as adaptation strategy in Ethiopian livestock production system. Moreover, participatory disease surveillance and control, relying on syndromic surveillance is also recommended as important strategy for climate change adaptation in animal health (FAO, 2008).

#### **4.5.5.4. Diversification (from cattle to smaller animals)**

Animal mix diversification has the potential to decrease the vulnerability of the herd to climate change, depending on the livestock species chosen. There are differences among livestock species in their ability to produce under given climate change (World Bank, 2011). Small animals including sheep, goat and poultry can easily adapted in area of feed shortage, however, the economics of herd diversification, for example from cattle to small ruminant or poultry depends on the relative costs of different species and relative revenues, both under current and future climate condition.

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## 5. Climate Change Mitigation in Ethiopian Agriculture

### 5.1. General

Climate change is an adverse condition that affects human and animal welfare, the production of crops and livestock and the efforts in economic development. Mitigation is an action or a series of actions taken to reverse or to stop an adverse situation. The causes of climate change associated with GHG emissions are either natural or human induced or both. The mitigation actions discussed below relates to the human induced actions that results in global warming and then climate change. The human induced causes for climate change related to agriculture could be associated with the production of crops, the production of livestock and the management of natural resources.

Ethiopia's current contribution to the global increase in GHG emissions since the industrial revolution has been practically negligible. Even after years of rapid economic expansion, today's per capita emissions of less than 2 t CO<sub>2</sub>e are modest compared with the more than 10 t per capita on average in the EU and more than 20 t per capita in the US and Australia. Overall, Ethiopia's total emissions of around 150 Mt CO<sub>2</sub>e represent less than 0.3% of global emissions (CRGE 2011). Ethiopia's contributions to GHG emissions come from agriculture, industry, transport and construction. It is reported that agriculture and agriculture-related activities such as forestry are the main contributors. In terms of amount, agriculture consisting of crop production and animal production represent 50 % of the emission while forestry results in the emission of 37 % of the total amount (CRGE, 2011). Therefore, the discussion attempts to identify the major sources contributing to climate change and the possible mitigation actions in relation to the production and management of the above-named commodities. It should, however, be noted from the outset that because of inadequacy of relevant and/or reliable empirical data related to the subject, coverage could not be comprehensive enough to meet rigorous standards on the subject.



## 5.2. Emission from Agriculture

### 5.2.1. Emissions from crop production

According to some local area study estimates, lands that are converted from other uses to crop production amount to 25% in 25 years (Zelege et al., 2014), i.e., 1% per year<sup>8</sup> on average. If we assume the same rate applies


uniformly throughout the country, this would mean that 1,213,691 ha of land is converted to cultivated use every year. Emission of carbon dioxide from this additionally cultivated land is equal to 130,088,256 tones CO<sub>2</sub>e per year, assuming organic matter content of 1.2% and a bulk density of 1.4 gm/cm<sup>3</sup> (1.4 tons/m<sup>3</sup>) in the soil to a depth of 30 cm. If this expansion of land for cultivation can be stopped by producing more through intensive means of production such as use of better yielding crop varieties (improved or selected), use of fertilizers (inorganic as well as organic), better cultural practices such as timely ploughing, sowing, weeding, reduction of post-harvest loss, etc., the land saved from cultivation would serve as a good carbon sink.

#### 5.2.1.1. Use of agricultural chemicals

Agricultural chemicals, in this context, mainly include fertilizers and crop protection chemicals such as pesticides. It would be noted that sources of fertilizers include both organic and inorganic forms, with the former contributing the largest emissions. Although Ethiopian farmers have traditionally relied on the use of organic fertilizers in the form of animal manure and compost, this has changed dramatically since the mid-1960s when chemical fertilizers in the form of DAP and Urea were aggressively promoted. At the present moment, over 30 % of cropped area (ca 14 million ha) is treated with chemical fertilizers. Needless to say, this results in the release of CO<sub>2</sub> and N<sub>2</sub>O which contribute to climate change.

Another source of GHG emissions in this respect relates to activities undertaken in the production, transport and packaging of these chemicals. As may be known, these activities are associated with burning fossil fuels that are obvious sources of GHGs. Obviously, this aspect does not relate well to Ethiopia where most of these agro-chemicals are not manufactured to a

<sup>8</sup> CSA gives a figure of 2 – 3 % for the period 2008/9 to 2010/11 and CRGE estimates this at 3.9% per annum.



large degree. It is, however, useful to remember that these global aspects do also reflect in Ethiopia. We should also note that some agro-chemicals such as those used in the protection of some pests have been under production for some years now. Recently, one of the four fertilizer blending facilities has been inaugurated and will go into full-scale production.

The amount of fertilizers added to the soils is often much lower than the amount of minerals mined from it through harvested grain and straw (Mekonnen and Köhlin, 2008). This situation is common to nearly all the third world countries and it is much more acute in east African countries, including Ethiopia ((Mekonnen and Köhlin, 2008). Unless corrective measures are taken to counteract this (through use of organic and inorganic fertilizers), the mining process leads to negative nutrient balance leading to a net emission, although there is no hard evidence to prove this.

#### **5.2.1.2. Crop production management practices**

Farmers traditionally use tillage practices to prepare lands for crop production. Depending upon their technological and financial status, farmers tend to use farm machineries, tools and implements to do the job. These range from high power tractors and associated implements, animal drawn ploughs and hand tools. In all cases, these activities result in soil disturbance that enhances and accelerates the release of CO<sub>2</sub> and other GHGs to the atmosphere that enhances climate change over time. Other activities in crop production that contribute to GHG emissions include leaving land bare and using a single crop (sole cropping) in the crop production system.

There are three sources (synthetic fertilizers, manure and crop residues) for GHGs emission in crop production (CRGE, 2011). Among them 58% is contributed by synthetic fertilizers and use of manure as fertilizer and reintroduction of crop residues into the soil. In the business-as-usual (BAU) scenario, GHG emission from soil is estimated to increase from 12 Mt CO<sub>2</sub>e in 2010 to 61 Mt CO<sub>2</sub>e in 2030. A 9.5% annual growth rate of crop GDP will be necessary to sustain population growth, provide food security, and help achieve middle-income status by 2025 (Fig. 15).

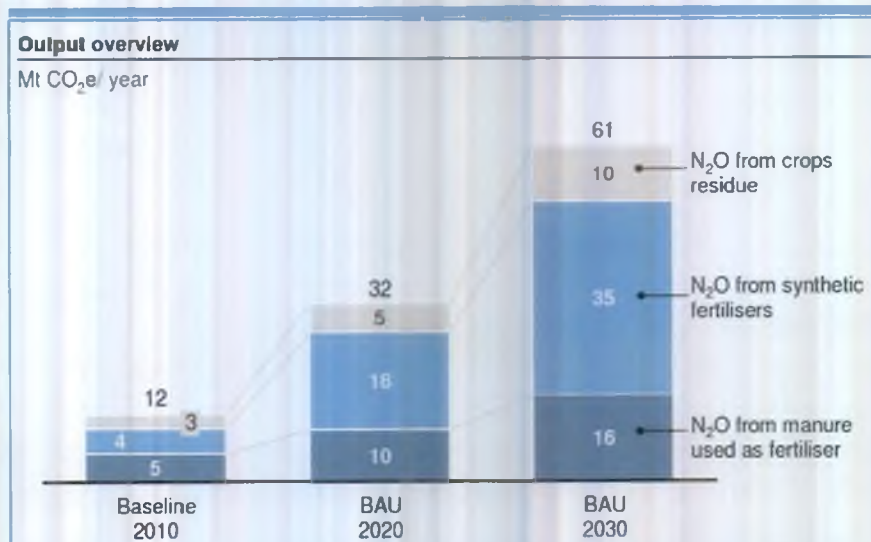


Figure 15. Project Soil –soil emission levels up to 2030 (Source: CRGE, 2011)

**Output overview**

Key emissions drivers	Projected change			Rationale
	2010	2020	2030	
<b>Total crop production</b> Million tonnes	19	36	71	* Crop production projection based on report by Dorosh (2007)
<b>Synthetic fertiliser hectare</b> kg/hectare	65	155	247	* Fertiliser/hectare targets based on similar land in India (World Bank data)
<b>Hectares cultivated</b> Million hectares	13	19	27	* Growth rate based on GDP, extrapolated to 2030 assuming no measures taken to increase agricultural yield/hectare
<b>Increase in livestock population</b> Million tropical livestock units	47	65	92	* 2008-11 growth rates from CSA projected until 2030

Figure 16. Four main drivers of emission from crop production (Source: CRGE, 2011)



Total cereal crop production is expected to increase from 19 million tons in 2010 to 71 million tonnes in 2030. It is assumed that residues from cereal crops are regularly reintroduced in the soil with the objective of improving the fertility of the soils as well as for sequestering C. This assumption need to be refined taking into account the local practices of feeding crop residues to livestock.

Total emissions from crop residue reintroduction were calculated using relevant emission factors for each crop. The rate of synthetic fertilizer application and the emission drive from the total area cultivated were calculated based on the assumption given above and the area covered by each crop. According to CRGE (2011) synthetic fertilizer per hectare will grow from 65<sup>9</sup> kg/ha in 2010 to 247 kg/ha in 2030. Synthetic fertilizer use in 2010 to 2015 was projected based on GTP targets, and usage growth until 2030 was estimated based on the World Bank 2015 fertilizer application estimate for India (247 kg/ha). This certainly a big jump from the current status but it is included in here just to conform to the already accepted Government position.

Hectares cultivated will also grow at 4% over the years based on projections from the GTP, which already includes programs such as improved seeds and fertilizer use. This will raise the area cultivated from 13 million hectares in 2010 to 27 million hectares in 2030.

### **5.2.2. Emission from livestock**

The livestock production system contributes to global climate change directly through the production of CH<sub>4</sub> from enteric fermentation and both CH<sub>4</sub> and nitrous oxide from manure management (CRGE, 2011). Among Ethiopian livestock species, the major contributor to GHG emission is cattle, which are used for meat, dairy products, as draught animals. Given current practices, the cattle population is likely to increase from today's around 53 million (CSA, 2013) to more than 90 million in 2030 (CRGE, 2011), thereby almost reaching the cattle carrying capacity of the country and doubling emissions from the livestock sector. As a sector, livestock holds nearly 20% of the total potential to reduce GHG emissions in Ethiopia (CRGE, 2011). In a business-as-

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<sup>9</sup> Other sources indicate much lower figures.

usual scenario (BAU), emissions from livestock are projected to increase as a function of livestock population growth from 72 Mt CO<sub>2</sub>e in 2013 to 124 Mt CO<sub>2</sub>e in 2030 (CRGE, 2011), mainly driven by an increase in methane from enteric fermentation and manure management (accounting for 112 Mt CO<sub>2</sub>e or 90% of emissions in 2030). Emissions from manure left on pasture range and paddock account for the remaining 10% of livestock emissions in 2030 (CRGE, 2011).

In Ethiopia's Livestock production context, dominated by small holder, the production and reproductive performance of the animal in any measurement are too low: poor feed conversion efficiency, poor daily weight gain, low milk and meat yield, low off-take rate, low conception and calving rate, longer calving intervals (Kiwuwa et al., 1983; Million et al., 2004) are some of the features. At the same time a large amount of GHG emission originate from the sector.

### **5.2.3. Emission from natural resources**

#### **5.2.3.1. Soil Erosion and land degradation**

A review of the existing studies<sup>10</sup>, which employed a range of methods and assumptions, indicate that the annual cost of land degradation figures arrived at is remarkably close. The estimates of these studies, which does not take into account the downstream effects such as flooding, is 2 to 3 percent of AGDP (Mahmud Yusuf et al, 2006).

It is estimated that about 2 million of land has been damaged beyond repair (changed to "badland"). It is also estimated that the country loses 30,000 hectares of land annually from water erosion. These losses are due to mainly water erosion which, according to a recent study, is estimated to be 20.2 t/ha/year (Hurni, 2014).

#### **5.2.3.2. Deforestation**

The tree cover of the country has been significant in the recent past. As

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<sup>10</sup> the Ethiopian Highlands Reclamation Study (EHRS); the Soil Conservation Research Project (Humi 1988); the National Conservation Strategy Secretariat (Sutcliffe 1993); the World Bank Reassessment (Bojo and Cassells 1995); Sonneveld (2002); and the Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2001a,b,c; 2002; 2003a,b; 2004a,b).

population and urban centers grew deforestation followed suit to meet the construction and energy requirements of the growing cities and the population at large. Large tracts of lands, in different parts of Ethiopia - especially in the rift valley, south and south western parts of the country - are cleared of their natural vegetation cover and converted to cultivated use. Several literatures state that Ethiopia had a forest cover of about 35% - 40% (some even estimate as high as 65%) in the past but this has dwindled down to less than 3% at the moment. The rate of destruction is estimated to be about 141,000 ha per year (Admassu et. al., 2013; Waithaka et al., 2013). Areas accessible to markets, close to towns and settlement areas were deforested much faster than the remotely located ones.

This denudation process was severe in particularly the long settled northern and central parts of the country that shortage of wood for construction and fuel was experienced to the point of concern by government even in the late 19th century. It was in recognition of this deforestation problem and concern for wood shortage that Eucalyptus (known to be one of the fast growing trees) was introduced and quickly propagated throughout the central and northern part of the country (Dessie and Erkossa, 2011).

The cause for the repeated drought and famine in the northern part of the country in early 1960s, mid 1970s and mid-1980s was believed to be due to climate change that resulted from deforestation, soil erosion and land degradation ([http://en .wikipedia.org/wiki/1983-85\\_famine\\_in\\_Ethiopia#background](http://en.wikipedia.org/wiki/1983-85_famine_in_Ethiopia#background)).

#### **5.2.3.3. Land conversion**

Over and above deforestation, which removes that area of the land from photosynthesis activities, the land that has been deforested is generally converted to cultivated use and there, the impact is much higher.

Lands are converted not only to cultivated or crop production landscapes but also to build up areas such as settlement (urban and rural villages) sites (Zelege et al., 2014) and to other built up areas such as roads, quarries, mines, airports, etc. Emission of GHG from such lands is much higher than the natural landscapes under forest and grass cover. For example, buildings



contribute about 5 Mt CO<sub>2</sub>e or 3% of the total emission [3Mt from solid and liquid waste in town and 2 Mt from off grid power generators] (CRGE, 2011)

#### **5.2.3.4. Desertification**

There exists a strong link between desertification, accelerated erosion, and climate change (Lal, 2012). Increase in temperature and decrease in effective rainfall provide a strong positive feedback which accentuates the rate of soil organic carbon (SOC) decomposition and emission of CO<sub>2</sub> into the atmosphere. Commonly, the words degradation and desertification are used interchangeably. It should be noted that desertification is a consequence of over exploitation to beyond its resilience thresholds (Lal, 2012).

#### **5.2.3.5. Grassland and Forest Fires**

Huge amount of carbon dioxide is released from burning of forests and grasslands. Grass and the included forest burning is a common practice in the moist lowlands of Ethiopia. Exactly how much area and biomass is burned is not known. Globally, land of the size of Africa is estimated burned every year (Savory, 2010). But regional breakdown is difficult to provide.

### **5.3 Mitigation of GHG Emission from Agriculture**

#### **5.3.1. Enhancing lower-emitting techniques for agriculture**

Emissions from crops are set to grow rapidly over the next 20 years due to carbon intensive crop residue and tillage management practices, and the increasing usage of organic and synthetic fertilizers. The introduction of lower-emitting techniques for agriculture offers an opportunity to check this increase of emission, while maintaining production levels. This initiative includes improved agronomic practices that increase soil carbon storage, nutrient management to more efficiently use carbon/nitrogen, improved tillage and soil management, integrated systems (mixed crop-livestock-agri-forest), and water management (irrigation, terracing, and other water-harvesting techniques). This initiative would complement the existing government plans to strengthen the agriculture extension system.

### 5.3.1.1. Soil nutrient and crop management

Improved agronomic practices can lead to increased soil carbon storage (Fig.17). Examples of such practices include: using improved crop varieties responsive to optimum external inputs (fertilizers and pesticides); sowing forage legumes in growing cereal crops, i.e., intercropping; adopting cropping systems with reduced reliance on external inputs e.g. green manuring, double cropping, and use of beneficial microorganisms and earthworms in compost making. Unless properly handled significant amount of nitrogen is lost through leaching or it may cause emissions. Employing techniques that could maximize the efficient use of nitrogen on crops reduces N<sub>2</sub>O emissions. Examples of such practices include adjusting application rates to crop needs and soil test-based nitrogen application; use of urea blended fertilizers urea granules, applying nitrogen at times when loss is minimal; splitting application rates between crop establishment and critical vegetative growth periods and manipulating soil chemical properties (such as liming) to release immobilized nutrients by raising soil pH to a neutral range.

### 5.3.1.2 Tillage/residue management.

Soil disturbance tends to hasten decomposition and erosion whereas reduced tillage results in soil carbon gain and reduction of CO<sub>2</sub> emissions. To achieve the latter effect, conservation agriculture will be promoted, including the use of zero and minimum tillage through the application of non-selective herbicides. The level of organic matter in the soil depends on the inputs from plant growth by reducing the losses due to erosion, harvesting, and microbial respiration. Even though returning crop residues into the soil is one of the main drivers of emissions, reintroduction of an increased amount can maintain or enhance soil quality and productivity through favorable effects on soil properties and life supporting processes. Reintroduction of crop residues increases the carbon stock of soil although it contributes to some emissions as well; but, on balance, it causes a reduction of greenhouse gases emission into the atmosphere as compared with other uses of crop residues such as using it as fuel and feeding it to livestock.



### **5.3.1.3. Watershed-based integrated farming systems**

Combining the production of livestock and food crops on land that also grows trees for timber, firewood, or other tree products would increase the standing stock of carbon above ground relative to equivalent land use without trees. Examples of practices of this type include shelterbelts, introduction of high-value tree crops such as fruit trees, agri-silvopasture practices like growing fodder trees within crop fields as source of livestock feeds, live fences, and multi-story crop production.

### **5.3.1.4. Water management**

This category includes the promotion of terracing, particularly in hilly regions with high soil erosion hazards, and the improvement of water harvesting and irrigation structures, such as providing supplementary irrigation by focusing on increased water use efficiency, which can enhance carbon storage in soils through enhanced yields and residue returns.

### **5.3.1.5. Irrigation in arid areas**

This initiative reduces emissions by creating new agricultural land out of uncultivated non-forest arid areas, thereby reducing the need for deforestation and avoiding the associated emissions. The STC estimates that a total area of 1.7 million hectares of new agricultural land could be created through small- and large-scale irrigation projects in arid areas based on estimates of total irrigable land (Bekele, 2009). Irrigation increases output from the land and avoids deforestation, both of which constitute economic benefits. The main sources used by the STC include surface irrigation potential estimates (Bekele, 2009; expert interviews, and statistics from MoWE, MoARD and IWMI).

Given an average carbon sequestration rate per hectare preserved of 53.5 tons of CO<sub>2</sub>e, the abatement potential in 2030 is 2 Mt CO<sub>2</sub>e for small-scale irrigation and 9 Mt CO<sub>2</sub>e for large-scale irrigation.



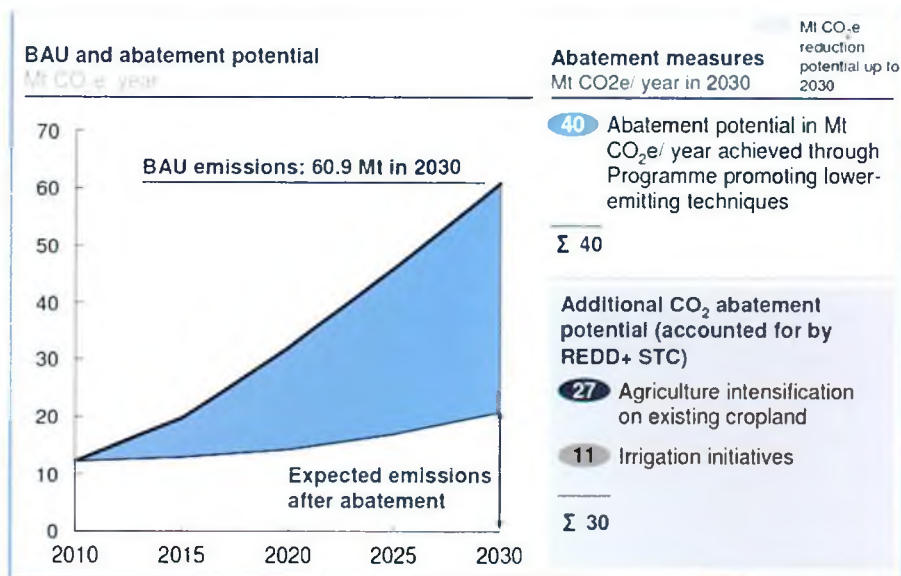


Figure 17. The mitigation potential of the crop-soil based agricultural management practices (Source: CRGE, 2011).

### 5.3.1.6. Reducing expansion of cultivated land

Keeping land under forest or grass cover not only serves as a sink for atmospheric CO<sub>2</sub> but also reduces emissions that come as a result of bringing more land under cultivation. As discussed above under this heading, the amount of CO<sub>2</sub> and N<sub>2</sub>O lost to the atmosphere from new lands is significant. However, this observation is based on theoretical considerations rather than actual experimentation at national (Ethiopia) level. The obvious mitigation practices that need to be considered in this respect is (a) minimize unnecessary clearing of forest lands and maintain grass lands in their natural state. Experiences in Ethiopia along these lines have not been encouraging; (b) on the other hand, afforestation of cleared lands, particularly in areas of steep slopes, has been a major undertaking of the public private sector over the last four or so decades. Despite such encouraging efforts, land clearing far outstrips land rehabilitation at the present moment.

Intensification of production is one possible way of stopping expansion of cultivation. Technologies are available to do this and promising results are

being seen in the recent decades. Use of better yielding varieties of crops, application of inorganic and organic (manure and compost) fertilizers, application of improved cultural practices such as timely seeding, weeding and harvesting as well as reduction of post-harvest losses, etc.

By raising annual growth rate of yield from the current BAU of 2% to 3.5% and by increasing the value growth rate of crops from 3.3% to 4% , it is projected that crop GDP target of 9.5% per year can be achieved without rapid expansion of land under cultivation (CRGE, 2011). This is believed to reduce the need for expansion of cropland from 3.9% (BAU) per year to 1.7% per year. These numbers are based on averages for lowland and highland areas. The Soil STC estimated yield and value growth rates under a yield-increasing program using historical trends for yield (CSA data) and value (Dorosh and Ahmed cereal price index). The total size of land saved from being cultivated is estimated to be 9.2 million ha (only 5.1 million additional ha is cultivated instead of 14.3 million projected for BAU by 2030). The proposed yield-increasing techniques include:

**Improved seeds:** Introduction of tissue culture, new varieties and high quality seeds to lower the incidence of pests and diseases and increase yield.

**Irrigation:** Introduction of basic/low-cost irrigation systems to allow continuity of production, especially in the dry season, reduces variability of output, and enables a shift to higher-value crops.

**Organic and inorganic fertilizers:** Increase usage of slow-release fertilizers and manure, thereby replenishing soil nutrients to ensure sustainable soil fertility.

**Best agronomic practices:** Introduction of planting, harvest, and post-harvest management best practices to lower the incidence of pests and disease, improve quality, and decrease spoilage.

The other option is diversification of the economy and engaging the farming manpower in these other economic sectors such as petty trading, manufacturing industry, construction sector and the like. This is of course easier said than done.

### 5.3.1.7. Intensification of production and improving cropping management practices

There are reports that the use of alternative cultivation practices could significantly reduce GHG emissions from soils. One of the most tested methods for the purpose has been what is called "Conservation Agriculture (CA)", although it could be called by other names. There is strong theoretical justification for suggesting this approach as it is shown to significantly reduce chemical reactions in the soil that result in the formulation and release GHGs such as CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. The main components of this cultivation practice are (1) minimum soil disturbance, (2) keeping land under cover and (3) the use of at least three crop species in crop rotation or sequences. Needless to say, there is no empirical evidence to prove this point in the Ethiopian context, although CA has been tested by various agricultural research centers and some NGOs. Their objective in testing this cultivation method is mainly limited to enhance crop productivity and reduce production costs.

If expansion of land for cultivation can be stopped by producing more through intensive means of production such as use of better yielding crop varieties (improved or selected), use of fertilizers (inorganic as well as organic), better cultural practices such as timely ploughing, sowing, weeding, reduction of post-harvest loss, etc., the land saved from cultivation would serve as a good carbon sink.

**Use of Inorganic fertilizers:** Use of Fertilizers in Ethiopia is one of the lowest in sub-Saharan Africa. According to Mekonnen and Köhlin(2008), annual losses of nitrogen, phosphorus and potassium in 37 sub-Saharan Africa countries is estimated at 4.4 million tons, 0.5 million tons and 3 million tons, respectively. These figures are overwhelmingly higher than the corresponding additions which is also estimated at 0.8 million tons of nitrogen, 0.26 million tons of phosphorus and 0.2 million tons of potassium, respectively. From this it is evident that there is heavy mining (depletion) on the soils of these countries. Quoting Sanchez et al. (1997), and Waithaka et al. (2007) state that "the countries with the highest levels of nutrient depletion are in eastern and southern Africa". Even within these, they add, "Ethiopia has one of the lowest rates of fertilizer use ..."



The recommended inorganic fertilizer application rate for the country has been 100 kg of di-ammonium phosphate and 50 kg of Urea per hectare for a very long time. These are the two main types of fertilizers used in crop production in Ethiopia. Recently, however, efforts are underway to come up with new recommendations. Fertilizer use adoption rate, however, is only by 37% of the farmers; and rate of application is much below the recommended rate - some assessments show below 15% of the recommended. The very ambitious CRGE states that the rate of application has reached 65 kg/ha by 2010 and projects to reach 247 kg/ha by the year 2030.

Assuming that even the lower the recommended level of application of fertilizers, i.e. 100 kg/ha DAP and 50 kg/ha Urea, will be realized, it is possible to get a yield increase of 25% - 40% for most crops. The biomass will also increase by about the same amount. If the produced biomass is incorporated into the soil the impact of its improvement on soil conditions, including the physical properties and fertility will be immense, even if some part of the biomass contributes to GHG emission. It is hoped that, with good management of this resource, expansion of land for cultivation would be checked or the rate reduced, with this amount of extra production.

The amount of fertilizer used shows a steady linear growth from 2002 to 2011 both for DAP and for Urea. It grew from 150,000 tons in 2002 to 350,000 tons in 2011 for DAP and from 75,000 tons in 2002 to 200,000 tons in 2011 for Urea (IFDC, 2012). The area cultivated during this period was 12,800,000 ha. Assuming that the large commercial farms would apply the recommended rates, one can say it is the small holders that do not adhere to the recommendation. Excluding the other crops, which probably are fruits, vegetables and root crops, the farmers seem to have applied 26.15 kg/ha of DAP and 15.21 kg/ha of Urea which represent just about a quarter of the recommended rates for DAP and about a third of the Urea. This shows that there is plenty of room for increasing productivity and production on the already cultivated lands without requiring area expansion any more.

**Use of manure:-** Ethiopia has a livestock population that ranks 10th in the world and 1st in Africa. This includes cattle, equines, shoats, and camels. Their number is estimated to be equal to [5.6 – 6.22 per household in the highlands – average for E. Gojjam and S. Wello] 5.91 tropical livestock units

[TLU] per household. Among the livestock, 75% are believed to be found in the highlands while 25% are in the lowlands. These animals, which are estimated to number 94,536,000<sup>11</sup>, produce a large quantity of manure every day<sup>12</sup> - estimated to be 172,529,000 tons per year in the highlands alone.

Each farm household uses woody biomass and dung for its household energy requirement, essential for cooking and heating. Whereas the use of woody biomass for fuel have led to deforestation and land degradation, the use of manure for fuel has led to nutrient depletion in the soils. Deforestation and land degradation are serious environmental problems in Ethiopia.

In the highlands, where sedentary agriculture is practiced, most of the manure is used as fuel, especially in the central and northern part of the country, and only a very small fraction is used as manure. Even where it is used as manure, its use is generally limited to small area of land around the homestead or nearby farms. Edward (2004) states that “losses to crop production from burning dung and soil erosion are estimated at over 600,000 tonnes (of grain) annually or twice the average yearly requests for food aid” (Italics added).

Using the data they collected from 1520 households in 12 different sites in East Gojjam and South Wello during 2000, 2002 and 2005, Mekonnen and Köhlin (2008) state that “fertilizer use in Ethiopia is one of the lowest in sub-Saharan Africa. Particularly in the northern half of the Ethiopian highlands, use of dung as manure is also limited partly because of a significant level of dung consumption as a source of household fuel”.

As the use of woody biomass and manure for fuel are only complements and not substitutes of each other, energy sources outside of these two have to be looked for in order to make afforestation programs and use of manure as fertilizer to be successful. Even the use of biomass and manure can be saved considerably by bringing in efficiency element such as fuel saving stoves. Biogas production in rural areas and use of electricity in towns are other possibilities (CRGE, 2011).

<sup>11</sup> Based on population of 93 million of which is 89% live in the highlands, 86% rural and 5.91 TLU/HH.

<sup>12</sup> If we assume 5 kilograms of droppings per TLU per day the annual quantity will be 1825 kg or 1.825 tons.

Nevertheless, encouraging trends are showing up as, according to this study, the proportion of households who use manure showed increasing trend (52% in 2000 to 59% in 2002 and to 74% in 2005). Along with this, the average quantity of dung used as manure by a household also increased and the average quantity of dung used as fuel declined (Mekonnen and Köhlin, 2008).

It is evident from this that the opportunity to use manure as fertilizer is there. It is demonstrated by some studies that yields of crops can be increased substantially with the use of manure, especially in combination with inorganic fertilizers. For example, according to Negassa et al. (2005), the grain yield of hybrid maize (BH660) at 4 different locations on Alfisols (Alfisols at Shoboka, Bako Research Centre, Laga Kalla, and Walda) increased on average from 4.66 ton/ha to 5.99 tons/ha (an increase of 28.5%) with the use of 12 tons/ha of farm yard manure (Table 16).

**Table 16.** Effects of farm yard manure and NP residual effect (applied in 1997) on maize yield in 1998.

Main effect	t maize grain ha <sup>-1</sup>			
	Walda	Shoboka	Laga Kalla	Mean
N/P (kg ha <sup>-1</sup> )				
0/0	5.82	3.31	4.35	4.49
20/20	6.81	4.48	4.67	5.32
40/25	6.77	5.18	4.95	5.63
60/30	6.86	5.64	4.30	5.60
LSD(.05)	0.78	0.92	NS	0.47
FYM (t ha <sup>-1</sup> )				
0	6.45	3.64	3.88	4.66
4	6.36	4.85	4.25	5.15
8	7.04	5.74	5.19	5.9
12	7.04	5.74	5.19	5.99
LSD(.05)	NS	0.92	0.80	0.47
CV (%)	14.27	23.67	21.06	19.0

Source: Negassa et al. (2005)



The corresponding inorganic fertilizer effect was 4.49 tons/ha to 5.60 tons/ha (an increase of 24.7%) with the application of 60/30 kg/ha of N/P, respectively. The effect was even better when the inorganic and the organic fertilizers were used in combination, as can be seen in the table above.

If we assume that the whole manure is applied as fertilizer, the 172,529,000 tons of manure shown above could increase the production of maize over an area of 14,377,400 ha of land which would mean 19,121,900 tons of maize.

It is evident from this data that farm yard manure is a potential source for nutrients, especially when the number of cattle (6.1 head per household according to 1987 estimate by Dadhi et al cited in Negassa et al., 2005) that can supply this material is taken into consideration. Manure is not only supplying nutrients but also conditions the soil favorably as plant growth media, i. e. decreases the bulk density, increases the available water holding capacity, improves soil structure (water stable soil aggregates), supplies essential macro and micro nutrients, increases the available P and the organic matter content thereby increasing the carbon content of the soils by as much as 67%. Inorganic fertilizers alone did not have effect on either bulk density (and hence water holding capacity) or carbon content of the soils. Manure also plays a vital role in improving crop yields and sustainable productivity. It is evident from these soil conditioning effects that manure's microclimate changing ability and restoration of ecological balance is high. A large volume of literature elaborates these properties of manure. The beneficial effects of manure are more clearly visible in moisture deficient and nutrient poor areas like the northern part of the country than in moist and fertile areas.

**Use of compost:** - Use of compost, even for garden crops, is not very common in Ethiopia. This is so because of low awareness situation among the farmers. Farm stubble is also either grazed or removed from the fields for use as fuel or construction material or forage reserve for animals. This practice effectively mines the soils with no nutrient return to it. Very recently, however, government has recognized the importance of this situation and included promotion of organic fertilizers in its annual development plans (as of 1998) – i.e. practices of compost preparation and use and stubble tillage (Kassie et al., 2009). Advocacy by the agricultural extension staff everywhere on these topics is strong, although acceptance and adoption is not yet very

encouraging. Nevertheless, some effort is still continuing to be made to demonstrate the use of this material on the fields of “lead farmers”. Hence, some core extension work is just beginning to be established.

As the impact and effect of organic materials on soils is more visible in degraded areas with poor soils, acceptance and adoption seem to be much better in Tigray than anywhere else. In this respect some activities were under way in Tigray since 2002. The Bureau of Agriculture and Natural Resources (as it was called then) has been promoting the concept of compost making ‘package’, parallel with soil conservation activities, in 90 communities in 25 Woredas in more marginal areas of the Region. In their effort of comparative study, they found out that fields with compost treatment generally gave the highest yields under all the agro-ecological settings under different fertility status of the soils. Compost also out-performed inorganic fertilizers applied at the recommended rates. Because of this fact, farmers, who have learnt how to make and use compost effectively, are not interested in and have willingly withdrawn from continuing to use chemical fertilizers (Table 17).

**Table 17.** Descriptive statistics of variables from Ofla Woreda used in the analysis

Dependent variables	Description	Description	Std Deviation
Stubble tillage	Plots received stubble tillage (1 = yes; 0 = otherwise)	0.368	0.483
Compost	Plots received compost (1 = yes; 0 = otherwise)	0.170	0.376
Chemical fertilizer	Plots received chemical fertilizer (1 = yes; 0 = otherwise)	0.236	0.425
Wheat grain yield with compost	Wheat grain yield in tons per hectare	7.480	4.020
Wheat grain yield with chemical fertilizer	Wheat grain yield in tons per hectare	5.080	2.470

Wheat grain yield without compost and chemical fertilizer (control yield)	Wheat grain yield in tons per hectare	3.680	1.870
Barley grain yield with compost	Barley grain yield in tons per hectare	7.047	2.725
Barley grain yield with chemical Fertilizer	Barley grain yield in tons per hectare	5.583	2.380
Barley grain yield without compost and chemical fertilizer (control yield)	Barley grain yield in tons per hectare	3.217	1.960
Teff* grain yield with compost	Teff grain yield in tons per hectare	6.790	5.000
Teff grain yield with chemical Fertilizer	Teff grain yield in tons per hectare	5.228	2.665
Teff grain yield without compost and chemical fertilizer (control yield)	Teff grain yield in tons per hectare	3.450	2.780

Source: Kassie et al. (2009)

Just like farmyard manure, compost also have positive soil conditioning effects like increasing the moisture holding capacity, high organic matter content, low bulk density, supplying macro and micro nutrients to the plants, increasing productivity and production of crops, etc. Hence, the benefits from conservation farming such as use of compost, manure and stubble tillage lie not only in conserving but also in enhancing the natural resources thereby enabling the soils to act as sink to carbon dioxide (sequester carbon). Crop yields are often better and the residual effect of compost over the following years is strong to the extent that farmers do not need to apply it every year. Its impact is also more clearly visible in degraded areas with soils of poor



fertility.


Recognizing the potential use of compost and knowing that there is virtually no investor is involved in its production at commercial level, a company called "Soils & More Ethiopia [SME]", which is a joint venture between "Dutch Soil and More International" and "Farm Organic International PLC [FOI]", is investing 300,000 Euro to prepare compost from flower wastes it gets free of charge from flower farms in Ziway. It is known that the flower farmers (mainly roses) face problems of disposing the clipping waste of their roses and up to 50 trucks are said to be engaged every day in dumping this waste at landfills. It is further known that many farmers and municipalities produce enormous amounts of waste which could be recycled and used for productive purposes. Or else, this waste will emit methane that is known for its notorious effect on climate change by negatively acting on the ozone layer. Converting this waste to compost does not only mean converting waste to economic use but also contributing to lessening its impact on climate change.

Based on the objective of finding out the feasibility of organic farming in Ethiopia, Devi et al. (2007) conducted a study in 5 locations in Ethiopia and found out that "The cost of production for organic farming was about 40.6 % less than that for inorganic farming". Based on this study, which involved 100 farmers at each location, and the statistical data obtained from UNDP, they calculated the availability and demand for compost/vermi-compost, poultry manure, FYM and bio-pesticides for the whole of the country as shown in the Table 18.

Table 18. Elements available/required for sustainable development in context to Ethiopian farming system (ton/year).

Components	Quantity available (ton/year)	Quantity required (ton/year)
Compost/vermin-compost	1.6 x 10 <sup>11</sup>	3.25 x 10 <sup>10</sup>
Poultry manure	8.5 x 10 <sup>9</sup>	3.2 x 10 <sup>9</sup>
FYM	1.8 x 10 <sup>10</sup>	9.7 x 10 <sup>7</sup>
Bio-pesticides	Abundant	1.6 x 10 <sup>10</sup>

Source: Devi et al., 2007.



From this, it is evident that there is tremendous potential for developing organic farming in Ethiopia at virtually no cost on inorganic fertilizers.

#### **5.3.1.8. Use of agricultural chemicals**

Mitigating the effects caused by the use of agro-chemicals is not an option, particularly in Ethiopia where food insecurity is serious and recurring problem. The various national development plans very much emphasize and encourage the use of chemical fertilizers in the production of major and “food security” crops. There have been suggestions to substitute some of these imported chemicals through increased use of farm yard manure and crop residue in the form of compost. Although there is some indication of adoption of the system, the level applied is much below the threshold levels.

#### **5.3.2. Reducing emissions from livestock**

The production and productivity gap of small holder is much lower than the potential so that it is clear production and productivity will increase through utilization of improved technology and practices such as; improved feed and feeding, improved breed and breeding, improved health services, improved market efficiency, improved husbandry practices and improved management. Intensification and improvement of the aforementioned techniques inevitably leads to culling unproductive animals and reduced headcount which gives chance to farmers shifting to better management of fewer productive animals. As this shift enhances market oriented production system it automatically leads to increased off-take rate at early age which means quality live animal and meat for both export and domestic market. Increasing off-take rate is the major strategy in decreasing GHG emission per animal and decreased number of animals; and increasing socio-economic growth of the country in general and small holders in particular.

##### **5.3.2.1. Improving productivity through breeding**

The cattle population in Ethiopia has historically grown in line with the expansion of the population. The CSA projects a population growth rate of 2.62% annually, which will add 54 million people to Ethiopia’s population by 2030. The cattle population in mixed crop-livestock system is projected to increase over next seventeen years from 42.02 to 67.7 million



head of cattle by 2030, as the same time GHG emission from cattle is projected to increase from current 43 MtCO<sub>2</sub>e to 72 MtCO<sub>2</sub>e (Table 19).

Production and productivity of Ethiopian livestock is poor compared to other countries. For example milk production potential of indigenous cattle breed is low around 529-713 litter per lactation (Table 20). However, a good first generation Holstein Friesian crossbred cow with moderate level of management can produce from 1726 to 2428 liters of milk (Table 21). The Ethiopian highlands, where the majority of smallholder, peri-urban, urban and rural population lives, are naturally suitable for improved dairy production. If due emphasis is given to the effective functioning of key technological input and output markets, the cattle industry has huge potential to develop and contribute to mitigation of GHG emission. Artificial insemination (AI) and estrous synchronization are an efficient technology to deliver improved genotypes to a large number of dairy farmers in a short period of time. These techniques lead to replacing unproductive indigenous cow population with less number but more productive crossbred cows. This gives chance to farmers shifting to better management of fewer productive animals.

Based on cattle population in mixed crop livestock system for year 2013 and taking annual growth rate of 2.64%, cattle population size from year 2014-2030 was predicted under BAU (Table 19) and associated GHG emission was also projected for the same period to determine emission and expected abatement potential through crossbreeding with more productive breed (Table 22). In order to determine mitigation option, 13% of indigenous cattle population in mixed crop livestock system (major milk-shade area of urban and peri-urban) is assumed to be replaced by crossbred dairy cattle on top of what already exist, and productivity improvement of 400% of milk yield (using data from Table 20 and 21) and 13% increment in meat production (Mekonnen et al., 1987) from local breed vs. crossbreed was assumed by 2030. Results from this projection indicated that replacement of 13% of indigenous cattle population in dairy potential area by more productive cross-breeds will result in abatement potential equal to roughly 6 Mt CO<sub>2</sub>e per year by 2030, assuming the indigenous and cross-breeds will emit around 1.08 and 1.5 tons CO<sub>2</sub>e per year/head respectively (Table 22).



Table 19. Project business as usual (BAU) cattle population and GHG emission in the highland areas

	Unit	Year																
		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Local breed	Millions	41.43	42.92	44.42	45.92	47.44	48.96	50.48	52.00	53.51	55.01	56.49	57.95	59.37	60.77	62.12	63.42	64.66
Crossbred	Millions	0.59	0.65	0.72	0.80	0.89	0.98	1.09	1.21	1.34	1.48	1.64	1.82	2.02	2.23	2.47	2.74	3.04
Total herd	Millions	42.02	43.57	45.14	46.72	48.33	49.94	51.57	53.21	54.85	56.49	58.13	59.77	61.39	63.00	64.59	66.16	67.70
CH4	MtCO2e	39	40.74	42.36	44.00	45.66	47.35	49.06	50.80	52.54	54.30	56.07	57.85	59.63	61.41	63.18	64.95	66.69
N2O	MtCO2e	4.2	4.30	4.40	4.50	4.59	4.68	4.76	4.85	4.92	5.00	5.06	5.13	5.18	5.23	5.28	5.31	5.34
Total emission	MtCO2e	43.36	45.05	46.76	48.49	50.25	52.03	53.83	55.64	57.47	59.30	61.14	62.98	64.81	66.64	68.46	70.26	72.03

**Table 20.** Mean lactation milk, lactation length and calving interval of local breeds breed in Ethiopia

	Milk yield (kg/lactation)			Lactation length (Days)			Reference
	Dataset	Mean	S.e	No	Mean	S.e	
Indigenous cattle breed							
Arsi	3	589.33	124.8	4	258.67	18.65	Million et al. 2004; 2001;2006
Barca	3	713.24	39.9	3	247.67	31.8	Million et al 2001; Goshu Mekonnen et al. 1983
Boran	4	592.25	136	3	202	19.0	Million et al., 2001; GebeyehuGoshu 1999; Moges Dereje et al. 1998
Fogera	2	592.5	279.5	2	231	56	AsheberSewalem 1992, Mekonne et al.1987
Horro	2	529	21	2	201	28	Beyene Kebede 1996

**Table 21.** Mean lactation milk yield, lactation length and calving interval of crossbred dairy cattle in Ethiopia (F1 crosses)

Breed group	Milk yield (kg/lactation)			Lactation length (days)			Sources
	No	Mean	S.e	No	Mean	S.e	
½ Jersey* ½ Arsi	3	1869.67	250	3	351.67	13	Million et al. 2004; 2003
½ HF* ½ Arsi	4	1726.7	229	4	382.39	9	Million et al. 2004; 2001
½ HF* ½ Barca	3	2160.65	235	1	326		Million et al 2001; Goshu Mekonnen et al. 1983
½ HF* ½ Boran	4	2327.06	228	3	306.2	22	Million et al., 2001; GebeyehuGoshu 1999; Moges Dereje et al. 1998
½ HF* ½ Fogera	2	2428.65	95	2	400.45	14	AsheberSewalem 1992, Mekonne et al.1987
½ HF* ½ Zebu	5	1983.72	156	4	337.67		Kiwuwa et al, 1983

**Table 22.** Predicted GHG emission reduction through crossbreeding smallholder's indigenous cattle with exotic dairy cattle

Year	indigenous cattle population	Amount of cattle reached by the program	number of indigenous cattle to be replaced	Amount of cross-breeds cattle produced	Emission reduced (MtCO <sub>2</sub> e) from reduced cattle	Emission increase <sup>1</sup> (MtCO <sub>2</sub> e) from crossbred animal produced	Net emission (MtCO <sub>2</sub> e)
2014	41435122	36318.056	26318.06	10000	0.028	0.002	0.026
2015	42918738	108954.17	78954.17	30000	0.085	0.006	0.079
2016	44416221	417657.65	302657.6	115000	0.327	0.022	0.305
2017	45924681	988239.24	716132.4	272106.87	0.773	0.053	0.721
2018	47440967	1558820.8	1129607	429213.73	1.220	0.083	1.137
2019	48961648	2129402.4	1543082	586320.6	1.667	0.114	1.553
2020	50482996	2699984	1956557	743427.46	2.113	0.144	1.969
2021	52000974	3270565.6	2370031	900534.33	2.560	0.175	2.385
2022	53511214	3841147.2	2783506	1057641.2	3.006	0.205	2.801
2023	55008998	4411728.8	3196981	1214748.1	3.453	0.235	3.217
2024	56489237	4982310.4	3610455	1371854.9	3.899	0.266	3.633
2025	57946448	5552892	4023930	1528961.8	4.346	0.296	4.049
2026	59374727	6123473.6	4437405	1686068.7	4.792	0.327	4.466
2027	60767724	6694055.2	4850880	1843175.5	5.239	0.357	4.882
2028	62118609	7264636.8	5264354	2000282.4	5.686	0.388	5.298
2029	63420041	7835218.4	5677829	2157389.3	6.132	0.418	5.714
2030	64664131	8405800	6091304	2314496.1	6.579	0.449	6.130

<sup>1</sup>Emission increase per crossbreed animal =0.1938 adapted from IPCC



### 5.3.2.2. Feedlot practice by smallholder farmers in mixed crop-livestock system

About 66% of smallholder cattle are assumed to be covered under feedlot program by 2030. Meat productivity improvement of 5% through selection, 10% through feedlot fattening and 50% reduction in fattening period (from 6 months to 3 months) were assumed (CRGE, 2011) in order to calculate abatement potential from application of improved feedlot practices in the mixed crop-livestock system. It is expected that these practices will increase the meat per animal brought on the market and therefore reduce the amount of cattle needed. The abatement potential equals to roughly 3.86 MtCO<sub>2</sub>e by 2030 (Table 5.8).

**Table 23.** Mitigation options through application of improved fattening practice

Year	Total cattle population in the highland	Projected Feedlot cattle reached	Number of cattle selected for meat	Reduction in cattle number as result of feedlot practice	Emission reduction <sup>2</sup> due to reduced cattle number (MtCO <sub>2</sub> e)	Emission increase <sup>1</sup> as a result of application of fattening technique (MtCO <sub>2</sub> e)	Net emission reduction (MtCO <sub>2</sub> e)
2014	41435122	3339641	3000000	339641	0.37	0.06	0.30
2015	42918738	5566069	5000000	566069	0.61	0.11	0.50
2016	44416221	11132138	10000000	1132138	1.22	0.22	1.01
2017	45924681	13382413	12021423	1360990	1.47	0.26	1.21
2018	47440967	15632689	14042846	1589843	1.72	0.30	1.41
2019	48961648	17882965	16064269	1818696	1.96	0.35	1.62
2020	50482996	20133241	18085692	2047549	2.21	0.39	1.82
2021	52000974	22383517	20107115	2276402	2.46	0.43	2.02
2022	53511214	24633793	22128538	2505255	2.71	0.48	2.23
2023	55008998	26884069	24149961	2734108	2.95	0.52	2.43
2024	56489237	29134345	26171384	2962961	3.20	0.57	2.63
2025	57946448	31384621	28192807	3191814	3.45	0.61	2.84
2026	59374727	33634896	30214230	3420666	3.69	0.65	3.04
2027	60767724	35885172	32235653	3649519	3.94	0.70	3.25

2028	62118609	38135448	34257076	3878372	4.19	0.74	3.45
2029	63420041	40385724	36278499	4107225	4.44	0.78	3.65
2030	64664131	42636000	38299922	4,336,078	4.68	0.83	3.86

1 assuming a minimal increase (2%) of emission per year of fattened animals, 2GHG emission of 1.08 MtCO<sub>2</sub>e for indigenous cattle was used (adapted from IPCC, 2006).

#### 5.1.1.1. Improved feed and feeding management

Methane production is influenced by dietary characteristics as well as the fermentation conditions in the rumen. In addition to this animal production level and management (grazing, feeding system, housing and milking affect methane production. Because of the multiple factors that may have changed simultaneously and have affected rumen fermentation and hence CH<sub>4</sub> yield, the effect of nutritional measures on VFA and CH<sub>4</sub> production may be difficult to predict and interpret (Frank et al., 2000).

Efforts to improve efficiency by reducing methane formation in the rumen directly have been of limited success, it is recognized that improvements in overall production efficiency will reduce methane emissions per unit of product produced. Literature results indicated that increasing feed efficiency and improving the digestibility of feed intake are some of feed management options to reduce GHG emissions and maximize production and gross efficiency (Ominski and Wittenberg, 2006). The volume of feed intake is related to the volume of waste product. Enteric CH<sub>4</sub> emissions are highest when the animal is presented with poor-quality forage and has limited ability to select higher quality forage components as a result of reduced dry matter availability (Ominski and Wittenberg, 2006). Feed resource in the mixed crop livestock system in Ethiopia are mainly natural grazing, crop residues, aftermath grazing. These are characterized by poor quality (Tesfaye, 2008). Improving the quality of these feed is an important strategy to reduce methane emission from livestock


**Concentrate supplementation:** Changes in feeding system (e.g. roughage: concentrate ratio may reduce methane emission. Compared to forages,

concentrates are usually lower in cell wall components ferment faster than forage, giving rise to elevated levels of propionic acid. Veen (2000) suggest that CH<sub>4</sub> production can be lowered by almost 40% (from 272 to 170 g/day) when a forage rich diet is replaced by a concentrate rich diet. Supplementation with concentrate feed especially for dairy cattle in potential dairy area is the best feeding strategy to reduce GHG emission from cattle (Bannink et al., 1997).

**Supplementation of molasses block:** Research in the past has clearly illustrated that supplementation of cattle on low quality forage based diets increases productivity through increasing efficiency of feed utilization (Leng, 1990; Mesfin et al., 2013). A mixture of nutrients as can be supplied for instance in a molasses urea multi-nutrient block lick ensures an efficient microbial digestion in the rumen (Getue et. al., 2013). A small amount of protein meal that is directly available to the animal (i.e. bypass protein) stimulates both productivity and efficiency of feed utilization. Provision of molasses urea blocks to draught oxen which in general receive only straw in most developing countries will have a major effect on methane production, reducing it to perhaps half the present production rate (Leng, 2009).

**Improved forage and pasture:** Methane production in ruminants tends to decrease with the quality of the forage fed. Study conducted on steers indicated that CH<sub>4</sub> emissions of grazing steers that had access to high quality pastures declined by 50% compared to emissions from matured pastures (Karin, 2001). Boadi and Wittenberg (2002) have demonstrated that forage quality has a significant impact on enteric methane emissions. Efficiency of forage fermentation was linked to biomass availability and quality of pasture. Further, it appeared that emissions were influenced by pasture dry matter availability and quality, in that emissions were highest (11% of Gross energy intake) when pasture quality and availability were low. Study conducted from New Zealand (Ramirez-Restrepo & Barry, 2005) indicated that feeding forage legumes like Lucerne or red clover also tends to decrease CH<sub>4</sub> losses compared to grass. Proper pasture management through rotational grazing would be the most cost-effective way to mitigate GHG emissions from mixed crop-livestock production. Animal grazing on pasture also helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils. The effect of different feeding strategy (concentrate supplementation, improved





forage legume, rotational grazing) on methane production by ruminant need to be further investigated by research under Ethiopian condition.

#### **5.1.1.2. Diversification toward lower emitting animal species**

Beef is the primary meat consumed in Ethiopia, and the demand for beef is a major driver of the size of the cattle population in addition to the requirement for draft power. Beef production is far more carbon intensive than the production of other types of meat (CRGE, 2011). In Ethiopia, poultry specifically chicken meat offers a particularly attractive lower-carbon alternative to beef. Partial replacements of cattle with lower emitting species (poultry, sheep and goat, fish) would be an alternative option for mitigation of GHG emission from livestock. These low-emitting animals are high feed converters and low GHG emitters as compared to large ruminants such as cattle (IPCC, 2006). These animals are high protein suppliers as well as high sources of income for the rural population.

#### **5.1.1.3. Mechanization**

Draft animals provide the animal power for the cultivation of nearly 50 % of the world's cultivated land and the pulling of 25 % carts (CRGE, 2011). Under the Ethiopian context, draught animals are the main source of plowing, cultivation, harvesting, threshing. The introduction of mechanical equipment (e.g., tractors including 2-wheel tractors) for ploughing/tillage to fully or partially substitute for oxen among farmers in highland area is an alternative options for adaptation and mitigation of climate change. Currently oxen population constitute about 32% of indigenous cattle population (CSA, 2013) and used as sources of power for cultivation of crop land. Taking the oxen population of the year 2013 and annual growth rate of 2.64% of cattle population (CSA, 2011) as a base oxen population size from year 2014-2030 and associated potential GHG emission was projected. A projection of GHG emission reduction by substituting 25% of oxen population with tractor or mechanical equipment by 2030 in the highland mixed crop-livestock system was made. In the prediction model GHG emission originating from tractor was included. Results from this projection indicated that the abatement potential from replacing oxen population by tractor in mixed crop livestock production system is estimated to be about 5.47 MtCO<sub>2</sub>e by 2030 and emission from

introduction of tractors is estimated to be 0.261 MtCO<sub>2</sub>e by 2030 (Table 23). The net abatement potential is about 5.209 MtCO<sub>2</sub>e by 2030.

Table 24. Reduction in GHG emission through replacement of draft oxen with tractor or mechanical equipment in the highland

Year	Total indigenous cattle population	Total oxen population under BAU	No of oxen to be replaced by tractor or mechanical equipment <sup>1</sup>	Emission reduction from replaced oxen (MtCO <sub>2</sub> e)	No of tractor required to replace oxen	Emission from utilization of tractors (MtCO <sub>2</sub> e)	Net emission (MtCO <sub>2</sub> e)
2014	41435122	13352297	333807.425	0.361	1669.037	0.017	0.343
2015	42918738	13704798	685239.882	0.740	3426.199	0.035	0.705
2016	44416221	14066604	977210.546	1.055	4886.053	0.050	1.005
2017	45924681	14437963	1269181.209	1.371	6345.906	0.065	1.305
2018	47440967	14819125	1561151.873	1.686	7805.759	0.080	1.606
2019	48961648	15210350	1853122.537	2.001	9265.613	0.096	1.906
2020	50482996	15611903	2145093.200	2.317	10725.466	0.111	2.206
2021	52000974	16024057	2437063.864	2.632	12185.319	0.126	2.506
2022	53511214	16447092	2729034.527	2.947	13645.173	0.141	2.807
2023	55008998	16881296	3021005.191	3.263	15105.026	0.156	3.107
2024	56489237	17326962	3312975.855	3.578	16564.879	0.171	3.407
2025	57946448	17784394	3604946.518	3.893	18024.733	0.186	3.708
2026	59374727	18253902	3896917.182	4.209	19484.586	0.201	4.008
2027	60767724	18735805	4188887.846	4.524	20944.439	0.216	4.308
2028	62118609	19230430	4480858.509	4.839	22404.293	0.231	4.608
2029	63420041	19738113	4772829.173	5.155	23864.146	0.246	4.909
2030	64664131	20259199	5064799.836	5.470	25323.999	0.261	5.209

<sup>1</sup>About 25% of oxen population is assumed to be replaced by tractor; About 100 households will share 1 tractor=100 and each household will have 2 oxen; one tractor will replace about 200 oxen population (CRGE, 2011). The average annual emission from one head of cattle is 1.08 tone Co<sub>2</sub>e per year and the average emission of 1 tractor is 10.31 tone of Co<sub>2</sub>e (Dikshitaet.al., 2010; CRGE, 2011).

### 5.3.2.3. Manure management

Improved manure management using a wide range of activities, including proper drying to avoid methane emissions related to anaerobic fermentation, and use as fertilizer or bio-fuel (IPCC, 2006). Improved rumen ecology through additives, changes to the diet mix, manipulation of rumen flora, and vaccination against methane-producing organisms. Vaccinations against methane producing organisms have been successfully implemented in other countries and a research is required to observe the local potential in Ethiopia.

### 5.3.3. Reducing emissions by managing natural resources

Agricultural production has a long history in Ethiopia. Through this long history, lessons of ecosystem management, including land and livestock, have been learned. To counteract the problems of land degradation, different indigenous (spontaneously developed) soil and water conservation as well as afforestation measures were exercised in different parts of the country. That is how the well-known terraces of Konso have been built.

A recent survey indicates that there are 33 types of traditional technologies and 7 different approaches to soil conservation and land management practices in the country (Danano, 2008). These were the technologies used by the farmers to fight the adverse effects on production and productivity including climate change such as moisture loss, raindrop impact on the ground, nutrient loss, etc. These practices can be considered adaptation to or mitigation against the climate change effects.

The main cause of climate change is believed to be land conversion, i. e. changing of land from its naturally occurring status that has developed equilibrium with the prevailing situation to human induced status which is disturbance of this equilibrium. A good example of this is deforestation, establishment of cultivation, overgrazing, etc. The shift of the equilibrium leads to soil erosion and land degradation.

#### 5.3.3.1. Afforestation/Reforestation

Annual deforestation rate is estimated to be 141,000 hectares. Saving this means considerable contribution to mitigation effort. Afforestation/ reforestation efforts have been under implementation in the last 5 decades




but the rate at which it was progressing was not in balance with the rate of deforestation. This topic would be retreated in detail under biodiversity.

Afforestation/reforestation is also a campaign that has to be run for several years at a very high rate. This can be done as a stand-alone action or in combination with soil and water conservation efforts. It has to be seen in relation to agroforestry promotion also.

### 5.3.3.2 Agroforestry

A unique feature of Ethiopia's highland mixed agricultural system is their perennial woody species composition. Nearly all farmlands hold several trees of diverse species (Figure1); hence can best be described as 'traditional agroforestry or evergreen agricultural system'. Various forms of traditional agroforestry systems are practiced across the highlands of Ethiopia ranging from simple few species based parkland (scattered on-farm trees) agroforestry system to complex multi-storey agroforestry system. Parkland agroforestry is perhaps the most widespread covering large parts. Example of this kind of agroforestry is the retention of scattered indigenous trees such as *Croton macrostachyus* (e.g. in Gojam, Gondar), *Cordiaafricana* (e.g. in East Wollaga and West Shewa), *Faidherbiaalbida* (e.g. in Hararghe highlands and East Showa) and the like. Coffee-shade agroforestry system occurs in many parts of the country as well such as West, South and East where coffee is grown. The system composes diverse tree species depending on the original vegetation of the areas. Common species are *Croton*, *Cordiaafricana*, *Albiziagummifera*, *Acacia abyssinica*, *Millettiaferruginea*, *Ficussur*, *Ficusvasta*, *Aningeriaadolf-fredirica* and many more (Teketay and Tegineh 1991, Muleta et al. 2008). Farmers in southern Ethiopia such as in Sidama and Gedeo are well known for retaining many trees of *Cordiaafricana*, *Millettiaferruginea*, *Albiziagummifera*, *Podocarpusfalcatus*, *Celtisafricana* and others in their various agroforestry systems (Abebe 2005, Asfaw and Ågren, 2007). Tree species in these agroforestry systems can range from as few as 5 to as many as 200, while the stem density per hectare may also range from as few as 10 to over 300 stems. Asfaw (2002) found a total of 123 tree, 146 shrub, 25 climber and 135 herbaceous species in various agroforestry systems in Sidama agroforestry system. Abebe et al. (2006) also reported up to 120 different tree species from 144 coffee based home-garden agroforestry systems in



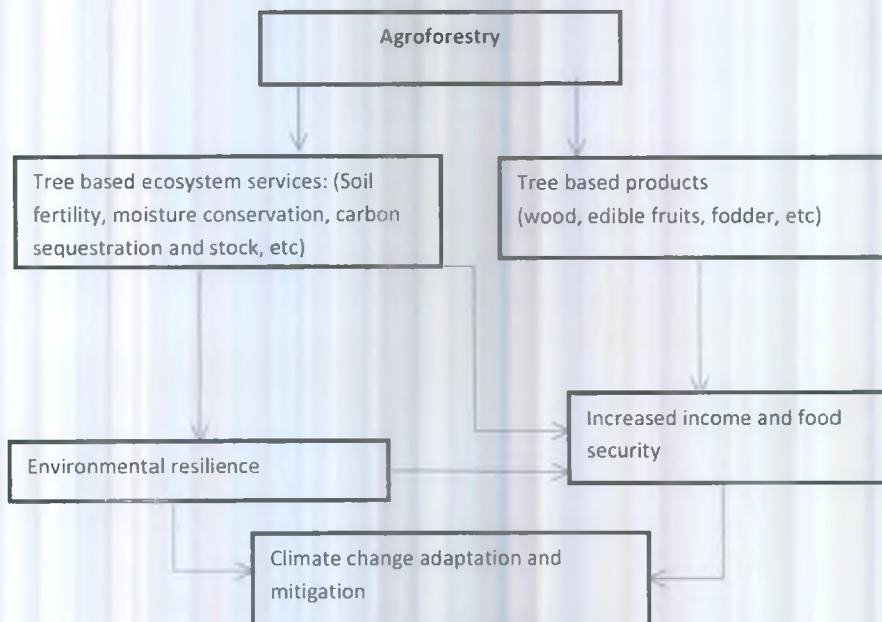
four districts of Sidama, southern Ethiopia. In parkland agroforestry system, average stem density of up to 52, 41 and 26 per ha were recorded in central, northern and eastern Ethiopia respectively (Hadgu et al., 2011). This indicates that the highland mixed farming systems in Ethiopia possess high potential for sequestering carbon and reducing other agriculture related GHG emissions.

Cultivated lands in Ethiopia with parkland agroforestry systems can reach up to 20 million ha, while those with high density trees such as multi-storey home garden and coffee shade agroforestry systems are estimated to cover some 2.32 million ha (Brown et al., 2012).

Perennial trees and shrubs that give the highland mixed agricultural system its evergreen character provide multiple supports to the agricultural system. The trees enrich soil carbon, reduce erosion and improve overall soil fertility that sustains agricultural productivity. This service is considerable given the characteristic low-input nature of the farming system. Soil improvement also implies improved soil moisture holding capacity, buffering crop failure during dry spells, which is becoming a major problem in recent decades. The trees are also important sources of dry season brows for livestock (Fig. 18). They also provide wood products (poles, fencing material and firewood) for home consumption and/or sell. The trees also sequester and store large amounts of carbon; hence role in climate change mitigation.

Agroforestry systems are increasingly recognized for the provision of both climate change mitigation and adaptation services (Fig. 18). It provides a medium for large quantity of carbon storage. Recognizing this, African Union Commission-New Partnership for African Development (NEPAD) led processes have called for the scaling up of agroforestry as a critical land use practice that can increase both current and future productivity under the specter of climate change.

In addition, agroforestry systems can meaningfully reduce the pressure on natural forests for energy needs. Development of agroforestry for sustainable fuel wood can contribute to energy substitution and becomes an important carbon offset option. Construction wood and fuel wood supply is one of the very obvious benefits of agroforestry. The unsustainable extraction of these products (construction and fuel wood) is one of the major drivers of deforestation in Ethiopia (Fig.18) given the heavy dependence on biomass



**Figure 18.** The role of agroforestry system in climate change mitigation and adaptation.

### 5.3.3.3. Soil Conservation and Land Rehabilitation

The cause for the repeated drought and famine in the northern part of the country, which claimed thousands of lives in early 1960s, mid 1970s and mid-1980s was believed to be due to climate change that resulted from deforestation, soil erosion and land degradation.

In an attempt to reverse this grave situation, the military government that took power by deposing the feudal system organized soil and water conservation campaign in the affected areas with subsequent expansion to other areas as well in the later years.

Prior to this period there never existed a government structure, let alone a government initiated program or project, responsible for soil and water conservation and for afforestation activities. When it was decided to conduct the program, a small unit was established for it within EPID. Obviously, such a huge task was impossible to expedite with a small unit that was established. Recognizing this fact the unit was quickly upgraded to the level of a department outside of EPID. At this time there was no research output



to guide what to do. There was no time to conduct a survey of the traditional conservation measures either. Hence, as a temporary stop-gap arrangement the very few experts that were available designed a simple technology to facilitate implementation with the technicians at field level who had no exposure to the subject at the start. This technology had to be implementable with the means available and with prevailing knowledge situation. Hence, instead of strictly following what is recommended by science, a one meter vertical drop was taken as the criterion for establishing contour lines along which soil conservation structures (contour bunds, fanyajuu, grass structure, etc.) had to be built. The implemented technology was simply copied from the Kenyan experience.

The effort made since mid-1970s and the recently started renewed effort is beginning to bear some fruits in some areas, especially in Tigrai and some areas of Amhara Region as the micro ecology appears to change after conservation work. This sign of healing is very encouraging and gives hope that it is possible to reverse the process somehow. Therefore this is an effective mitigation action.

According to one recent estimate (Hurni, 2014), the total area of rainfed crop production is estimated to be 18,751,262 ha. Out of this total area 14,335,015 ha or 76.5% is on slope of more than 8% and this area needs to be treated with soil conservation measures. So far only 3,354,393 (17.9%) of this area is covered in the last 40 years with some form of conservation work. At this rate it is believed that it would take 171 years to cover the remaining area. Obviously, we cannot afford to wait that long and we need to increase our effort. If the claimed recent achievement is true<sup>13</sup>, the time required will drop down to 5.49 years which is too hard to believe. Even if we can manage to complete this work in the next 25 years, it can be considered a commendable achievement. From then on it would only mean maintenance work.

The current soil loss rate from the cultivated lands is estimated to be 20.2 t/ha/year. This equals to 378,775,492 tons for the area of rainfed crop production. If conservation work is done in all areas with slopes of more than 8%, and the management is optimized, i. e. forage grass is produced on

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<sup>13</sup> It is claimed that 2 million hectares of land are treated with soil conservation measures every year.

conservation bunds and fertilizer is applied to all cultivated lands, this can be brought down to 11.8 t/ha/year which means a saving of 8.4 t/ha/year.

Assuming a soil organic matter content of 1.2% and a bulk density of the

	Area of rainfed cultivation, ha	Eroded soil under business as usual scenario, t/ha	Total amount of soil eroded (under business as usual scenario), ton	t/ha eroded under CBA scenario	Total amount of soil eroded amount (under CBA scenario), ton	Difference, ton	OM, ton	Carbon, ton	CO <sub>2</sub> e, ton
Total area of the country, ha	122,077,143								
Area of Water bodies, ha	708,047								
Land Area of the Country, ha	121,369,096	20.2	2,451,655,690	11.8	1,432,155,304	1,019,500,386	12,234,005	7,095,723	26,017,650
Area requiring conservation work, ha	92,847,357	20.2	1,875,516,603	11.8	1,095,598,808	779,917,795	9,359,014	5,428,228	19,903,502
Area of rainfed cultivation, ha	18,751,26	20.2	378,775,49	11.8	221,264,892	157,510,601	1,890,12	1,096,274	4,019,871
Cultivated areas with more than 5% slope, ha	14,335,81	20.2	289,567,303	11.8	169,353,127	120,214,126	1,444,970	838,082	3,072,968

An effective soil and water conservation action should also reduce desertification process and the cyclic annual practice of vegetation burning (slash and burn).

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## 6. Synthesis and Policy Implications

### 6.1 Background

Agriculture in Ethiopia has been practiced as a source of livelihood system for the majority of the Ethiopian population since time immemorial. This may be due to the country's great endowment with natural resources potentials that can greatly contribute to agricultural production and productivity. These potentials include abundant land resources estimated at over 117 million hectares over 60 % of which can be used for some form of agricultural activities, water resources with a potential to irrigate over 5 million hectares, bio-diversity resources in both crops and livestock, animal resources said to be the largest in the African continent, and agro-ecology resources suitable for the production of numerous crop and livestock types. To this must be added the great advantage of its geographic location that can be a major asset in international trade.

However, agriculture has basically remained as a "low input-low output" production system that inevitably resulted in low crop and animal production and productivity leading to frequent failures to meet the food and feed needs of the country's human and animal populations. The main contributors to this state of affairs include 1) unfavorable climatic factors such as lack or inadequate annual rainfall, hail storms, and temperatures leading to frosts and pest infestations; 2) the use of low performing traditional technologies such as indigenous crop and animal species of "low" genetic potentials; 3) application of inappropriate crop and animal production management systems that not only result in drudgery but also enhance land degradation and soil fertility depletion; 4) application of traditional value systems that give greater emphasis to prestige rather than efficiency and effective use of resources; 5) socio-cultural systems that fail to effectively encourage the participation of women in agricultural and social development; and 6) poorly developed value chain systems.

Agriculture in Ethiopia is extremely vulnerable to climate change or variability (CC/V). A range of climate change scenarios and models suggest that many parts of Ethiopia are likely to experience such climate change or variability in the future. Since Ethiopia's agriculture is overwhelmingly rainfall-dependent,




it continues to suffer greatly due to the vagaries of the weather. Long-term records indicate that there have been severe and repeated rainfall failures resulting in severe food/feed insecurity, including famines, on the Ethiopian population due to significant loss of crops and livestock.

The frequency and severity of natural shocks including rainfall shortage and rise in temperature has increased in recent years. Reports indicate that the average temperature in the country has been increasing at a rate of 0.20C per decade for the last 50 years. Similarly, there have been frequent changes in the amount and distribution of rainfall. The collective action of these important climatic changes or variability affect the performance of crops and animals through changes in suitability of areas for agricultural production; the length of the growing period as well as the rate of plant growth and development; the occurrence, development pattern and severity of plant and animal disease and other pests; and the management practices used for crop and animal production.

Erratic rainfall and excessive evapotranspiration due to extended dry season have been causing drastic crop yield reductions, or crop failures and decrease in herbage biomass yield and carrying capacity of grazing lands. Reports indicate that there have been major droughts in Ethiopia over the past centuries, 15 of which, in fact, occurred in the last 50 years or so.

Although food insecurity mainly caused by rain shortage or rain failures occurs in almost all regional states of the country, it is most frequent and severe in the dry lowlands and, to a limited extent, in the sub-moist mid-altitude areas of the country. The estimated number of people affected by food shortages in Ethiopia has varied significantly from year to year and from region to region. For example, reports indicate that the Ethiopian droughts of 1974 and 1984 were among the most severe events affecting over eight million people.

It is important to note that the government of Ethiopia (GoE) is aware of the implications of climate change in relation to social and economic development for the country. It has, therefore, formulated a policy and strategy document to combat such threat. This strategy is put forward in the Climate Resilient Green Economy (CRGE) strategy document published in 2011. It is useful to touch upon the policy and strategy of the Ethiopian Government in relation



to its future response in dealing with impending climate change/variability to help the country meet future challenges. It should be noted that CC/V has not been a central point of concern in development planning in the past. For example, the agricultural research agenda of the past was mainly concerned with improved factor productivity rather than response to CC/V. However, this attitude has begun to change since 2011 when the Climate Resilient Green Economy strategy was formulated. This strategy focuses on “Green Economy” that aims to reduce greenhouse gas emission.

## **6.2. Impact of Climate Change/Variability**

Climate change or variability, as has been briefly indicated above, has impacted on humans and their livelihoods. Especially extreme events like droughts, floods, frosts and landslides associated with high rainfall particularly in deforested and/or overgrazed areas have resulted in the loss of human and animal life as well as in property. For example, the floods of 2006 in various regions of the country affected around 675,000 people, displaced about 242,000 and caused about 720 casualties. The impacts of climate change or variability can be associated with the following:-

**Impact on Crop Production:** Ethiopia is endowed with a large number of crop species adapted to a wide array of agro-ecologies obtaining in the country. Similarly, it is estimated that over 60 % of the country’s land resources are suitable for various types of agricultural activities. Accordingly, there have been efforts underway to utilize these resources as much as possible to increase agricultural production and productivity. However, such expansion can be negatively affected by climate change and/or variability in the medium and long-term period unless appropriate precautionary methods are developed and implemented. The main areas of negative impact could be the following.

**Impact on Length of Growing Period:** It is known that the length of the growing period of crops is affected by, inter alia, the amount and duration of rainfall as well as by high or low temperatures. As has been mentioned earlier, there has been an increasing trend of temperature increase over the past decades and is projected to continue over the long term. It is known that plant development leading to maturity will accelerate under high temperature regimes as




compared to cooler conditions, even if there is sufficient soil moisture. This condition impacts on production and assimilation of plant nutrients leading to early flowering, seed setting and senescence thus resulting lower production and productivity. It may be argued such events will favor tropical (C4) crops such as maize, sorghum and tef, but this will have temperature limits above which the boom turns to bust.

**Impact on Suitable Areas of Production:** It is anticipated that sustained rise in temperature will shift suitable crop areas for many of Ethiopia's traditional major crops to higher altitudes compared to their present areas of production. This will result in gains for some crops while there will be a loss for others. Projections under Ethiopian conditions seem to suggest that under warming conditions maize, tef, sorghum and barley will lose over 14, 11, 7 and 31%, respectively, of their current suitable area of production by 2020 and will further increase by 2050. It should be noted that the impact will be relatively lower on tropical (C4) crops like maize and sorghum as compared to temperate (C3) crops like barley and wheat.

**Impact on Productivity:** The productivity of crops hinges on various climatic factors such as rainfall, temperature and atmospheric CO<sub>2</sub> concentration. It should be noted that the concentration of CO<sub>2</sub> in the atmosphere is one of the causes for increase in temperature due to what is known as the "Green House Effect". Increased CO<sub>2</sub> in the atmosphere should enhance crop productivity due to increased photosynthesis; however, this positive effect could be nullified because of its effect in raising atmospheric temperature resulting in negative crop productivity. Experimental projections using various climatic models carried out in some parts of the country on maize and wheat show that maize productivity could increase by a certain percentage points up to 2050 but decrease substantially by end of the century whereas wheat yield consistent decrease till the end of the century.

**Impact on Diseases and Pests:** Crop loss to pests and diseases are expected to reach 16 % and 18 %, respectively, globally. However, there is no clear and consistent yield loss figures for crops and regions in Ethiopia, although there are indications that such losses could be as high or higher than indicated above. In any case, it is expected that increases in temperature will increase the activity range of diseases, insects and invasive weeds quite significantly thus resulting in increased crop loss, at least during crop growth in the field.





Impact on Livestock Production: The impact of climate change on livestock production could be both direct and indirect. The direct effects include the effect of temperature and rainfall on animal productivity (i.e., animal growth, reproduction and milk/meat production), while the indirect effects relate to factors that are essential to livestock development and performance.

Impact on Herd Dynamics: The greatest factor on the impact of climate on herd dynamics is related to rainfall amount and distribution. Cattle herd dynamics is strongly influenced by rainfall variability. Herd size has been observed to decline drastically due to droughts whose frequency and intensity has worsened over the past several decades in the southern lowland areas of the country where livestock production is the main form of livelihoods. For example, the droughts of the 1980s and 1990s caused 49% herd losses under the communal land use, while 57% of the cattle mortality under ranch management was attributed to droughts of the 1990s. It is interesting to note, however, that herd size recover quite rapidly after recovery from droughts.

Impact on Animal Feed and Forage: Experimental data on the effect of climate change or variability on the availability of animal feed such as forage quality and quantity as well as on species composition and nutrient content is lacking in Ethiopia. It is expected, however, that as temperature changes optimal growth ranges for different forage species also change, species alter their competition dynamics, and the species composition of mixed grasslands changes. Some observers have noted that climate change can be expected to have several impacts on feed crops and grazing systems including the following:

Changes in herbage growth brought about by changes in atmospheric CO<sub>2</sub> concentrations and temperatures;

Changes in the composition of pastures, such as changes in the ratio of grasses to legumes;

Changes in herbage quality, with changing concentration of water-soluble carbohydrates and N at given dry matter (DM) yields;

Greater incidences of drought, which may offset any dry matter yield increase;

Greater intensity of rainfall, which may increase N leaching in certain systems

**Impact on Livestock Diseases:** It should be noted at the outset that good quality and quantified data on the effect of climate change or variability on livestock diseases in Ethiopia is quite scanty. As discussed in the crops section, livestock diseases can be expected to show different patterns in behavior and geographic distribution in response to climate change or variability. This has been observed in relation to livestock diseases such as Trypanosomiasis and Rift Valley Fever. For example, there is evidence to show that the tsetse fly distribution in Ethiopia has resulted in a gradual encroachment of the country's central highland plateau. Data from different sources indicated that the amount of land infested by tsetse fly in Ethiopia 22 years ago was estimated between 66,000 and 97,855 km<sup>2</sup>. This figure has increased in 15 years-time from 135-180,000 km<sup>2</sup> to 220,000 km<sup>2</sup>. This has resulted in putting large area of the country unsuitable for the introduction of better performing livestock species.

**Impact on Agricultural Water Resources:** It is known that climate change or variability will affect agriculture water supply through its effect on increasing atmospheric temperature and on amount and distribution of rainfall. The projected increase in temperature across Ethiopia, as shown by some observations and climatic modeling, will increase water demand by crops by increasing evapo-transpiration. On the other hand, there is no clear picture on water supply since some areas are projected to have increased rainfall while others will have reduced amount. However, the areas with increased rainfall are expected to be affected by rainfall intensity over a very short period of time resulting in floods and serious soil erosion, while those with decreased rainfall will face serious draughts resulting in drying rivers and lakes in addition to soil re-change problems.

**Impact on the Economy:** Needless to say, the impact of climate change or variability on the national economy is quite substantial, as CC/CV impact on crop and livestock production that the main sources of revenue for the national economy. For example, there is a study in some parts of the country which indicates that increases in temperature of 2.50C and decrease in rainfall of 7% will reduce net revenue from crop production by over Birr 100.00 per hectare. Further changes in temperature and precipitation are project to affect revenue in crop production as indicated below:

Climate change scenarios	Change in net revenue (in ETB)
+ 2. 0C Temperature	-1812.43
+5 0C Temperature	-3039.67
-7% in precipitation	-1609.01
-14 % in precipitation	-2676.71

Source: Gebreegziabher et al., 2013.

Climatic changes will also negatively affect net revenue from livestock production. The following Table shows the results of some studies on the impact of climate change on income from livestock production. The Table also shows the impact of climate change on the whole agriculture. As a consequence of these impacts on crop and livestock both of which are dependent on seasonal rainfall, the country's GDP can be reduced by as much as 3-10% by 2025, according to some estimates.

Climate change scenarios	Change in net revenue (in ETB)	
	Livestock	Whole agriculture
+2.50C Temperature	-274.02	-1035.46
+5 0C Temperature	368.52	363.8
-7% in precipitation	-1112.45	-645.08
-14 % in precipitation	-1833.42	-1141.63

**Impact on Food Security:** A significant proportion of people in the crop dependent highlands are chronically food insecure. Moreover, by reducing crop yields, increasing land degradation, and lowering water availability, climate change places more pressure on the food security of millions of people in Ethiopia. For example, a bio-economic analysis using a maize as a case study indicate 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 not only on production but also on global agricultural import and export trade and prices.

### 6.3 Vulnerability to Climate Change/Variability

According to the Inter-Governmental Panel on Climate Change (IPCC), vulnerability is defined "as a degree to which a system is unable or to cope with negative effects of climate change". Vulnerability can be expressed in




terms of three variables, i.e., exposure, sensitivity and adaptive capacity. The two main drivers of vulnerability are climatic and non-climatic.

**Climatic Drivers:** As indicated elsewhere in this section, the major climatic factors influencing agriculture are mainly related to rainfall patterns and temperature regimes. Extreme events leading to serious negative consequences for agriculture include droughts and floods that have caused huge damage to human and animal life with serious consequence for the national economy and food security. Extremes in temperature result in physical damage to crops and animals in cases of temperature increases while frosts result in serious crop damage in cases of low temperature events. In any of these cases, Ethiopia's extreme weather events are fueled by global climatic drivers such as the El Nino and La Nina (ENSO) which are associated with shifts of warm tropical Pacific Ocean currents.

At regional level, the broad characteristics of the climate, with the recurring wet and dry seasons of Ethiopia, are largely determined by the annual movement across the country of the equatorial low pressure zones. Thus, the dry northeasterly winds and the moist winds of southwesterly origin typify the dry and wet season climate pattern respectively. With the exception of the southern part, Ethiopia receives rainfall during June-September period with the progression of the Inter-tropical Convergence Zone (ITCZ) towards northern Ethiopia on the Red Sea coast and Gulf of Aden side thus contributing to the tune of 90–95% of the national crop production. During this season, both the Atlantic and Indian Oceans contribute major rainfall to the country. The length of the rainy season varies over a period and place, depending on the length and duration of the predominant winds. More importantly, the space-time characteristics of the Ethiopian rainfall pattern are key indicators of both the potential for productivity and vulnerability of agriculture.

**Non-climatic Drivers:** The main non-climatic drivers of vulnerability in Ethiopia are associated with agricultural land use, demographic pressures, socio-economic and technological factors and poverty issues. Each of these drivers has their own causes and contributes to vulnerability of the agriculture sector. For example, misuse of land through deforestation, over-grazing and inappropriate farming practices results in land degradation, of which soil erosion is classic example. It is estimated that annual soil loss from



inappropriate land management practices in steep slopes could reach as high 300 tons/ha/year. Land exposed to such practices could also result in GHG emissions, according to the CRGE strategy document. These situations are further aggravated by population growth of over 2 % per year, inadequate socio-economic circumstances leading to poverty and inadequate availability or adoption of improved and more efficient agricultural technologies.

**Components of Vulnerability:** As indicated above, vulnerability can be describes in terms of exposure to mitigating climatic factors; sensitivity to these mitigating factors; and the ability, in terms of knowledge, resources and commitment to take measures to withstand mitigating factors. There have been some case studies on vulnerability and its components in some parts of the country. Therefore, results from these studies are summarized as follows.

**Case Studies on Exposure:** Studies in some of the Upper Awash and Central Rift Valley districts as well as in Choke Mountain areas show that levels of exposure to climatic shocks vary significantly across the districts, as some face more exposure due to increased temperature and decrease in rainfall while others are less exposed. Interview with local residents indicate that they are quite aware of these changes in climatic events over the last two or so decades.

**Case Studies on Sensitivity:** Case studies in the above mentioned districts also show variability in the level of sensitivity to climatic shocks as perceived by local residents as well as by observations. The major factors associated with sensitivity issues vary from place to place. These include bio-physical characteristics of the areas (such as land forms, forest coverage and soil conditions), population dynamics that influence size of land holdings, levels of poverty in the population as well as other socio-economic and technological endowments. Thus, localities with high number of people under poverty and small land holdings, highly degraded and rugged terrains, poorly developed infrastructures and market access and inadequate technological development were found to be more sensitive to climatic shocks than otherwise.

**Case Studies on Adaptive Capacity:** Adaptive capacity at a given scale is assessed using wealth, technology, infrastructure, community and social capital as a major criteria. Because all localities do not have similar socio-



economic, environmental, technological and infrastructural development, etc required they are endowed with different levels of adaptive capacities. Therefore, the above named districts are endowed with different levels of the above-named requirements, they are found to have different levels of adaptive capacities as found out from the various case studies.


**Case Studies on Integrated Vulnerability:** Integrated Vulnerability assessment considers the interaction between its three components in which exposure influences sensitivity; which means that exposure to higher frequencies and intensities of climate risk highly affects outcomes (e.g., yield, income and health). Exposure is also linked to adaptive capacity such that better adaptive capacity reduces potential damages from exposure. Sensitivity and adaptive capacity are also interlinked; given a fixed level of exposure, adaptive capacity reduces the level of sensitivity. Integrated analyses of vulnerability components in agriculture have been reported by some researchers.

Some studies on the vulnerability of some of the countries regions shows that the net effect of adaptive capacity, exposure and sensitivity varies greatly due to some natural or man-made endowments. For example, it is positive for SNNP and Benhangul Gumuz and negative for Afar, Amhara, Oromia, Somali and Tigray. Whilst SNNP and Benishangul Gumuz are less vulnerable, Afar, Amhara, Oromia and Somali are vulnerable to climate change with varying magnitude The lesser vulnerability of SNNP is explained by its relatively higher access to technology, as the percentage of farmers in this region have relatively better access to insecticides, pesticides, fertilizer, and supplies of improved seeds and food market, and its highest irrigation potential and literacy rate compared to other regional states. For Afar and Somali, vulnerability is associated with lower levels of rural service provision and infrastructure development. For example, a study in Borena zone highlights low investment in services and infrastructure, inadequate policies and institutions as well as social and gender inequalities and environmental degradation.

#### **6.4. Adaptation to Climate Change in the Mixed Crop-Live-stock Systems**

There are considerable evidences that the global climate is changing and





projections suggest that the rate of change will increase in the future. Warming has occurred across much of Ethiopia, particularly since the 1970s at a variable rate, but broadly consistent with wider African and global trends. Daily temperature observations show increasing frequency of both hot days and hot nights. Climate models suggest that Ethiopia will see further warming in all seasons, between 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s.


**Adaptation Options and Strategies:** A wide range of adaptation options that are thought to reduce agriculture's vulnerability to climate variability and change are pursued both at macro- and micro-levels. The government of Ethiopia has taken up the issue of climate change in general and adaptation in particular as a priority agenda in the transformation of the nation's agriculture. In line with the national food security macro-level initiatives, the government is pursuing different adaptation strategies such as operationalization of agro-weather advisory service extension at full blast and response mechanism, safety net programs, natural resource management. Weather index based insurance transaction is also seen as a national priority adaptation activity to reduce short term vulnerability among socio-economic systems by addressing the risk of serious inter-annual and inter-seasonal rainfall fluctuations. Since smallholder dryland farmers are highly susceptible to weather driven risks and disasters, both agroweather advisory services and weather based insurance initiatives can enable them to withstand the loss that they most likely face as a result of seasonal fluctuations or rainfall variability. Another project-based adaptation mechanism promoted by the government and donors is early warning and response mechanism which focuses on strengthening the capacity of national and regional offices of the National Meteorological Agency, the Ministry of Agriculture, and the Ministry of Water, Irrigation and Energy. This helps to monitor climate change, generate reliable hydro-meteorological information, and combine the collected facts with environmental and socio-economic information. The government's Safety Net Program is also used as adaptation mechanism to improve the food security of the poor while facilitating the engagement of the local communities in improving natural resources management through food/money for work arrangements. The work includes soil and water conservation structures, planting trees in degraded slopes, and protecting

landscapes from excessive use by livestock through 'area enclosure'. Farm level studies indicate that farmers are constrained by a range of barriers which impede adaptation efforts; the most important barriers include lack of climate information/awareness and technical knowledge, shortage of labor and land, poor potential for irrigation, lack of financial capacity, lack of suitable drought resistant crops/species and improved seed, inadequate farmer capacity and training, and lack of understanding of adaptation processes, inter-departmental conflicts, inadequacy of local government's commitment and community participation, issues of 'territoriality', and lack of guiding principles and limited understanding at Wereda and Kebele levels.

**Community-Based Adaptation Strategies:** Among the adaptation strategies that farmers carry out are using appropriate crop varieties, adjusting planting dates, use of soil and water conservation techniques (employing water harvesting techniques, improvement or rehabilitation of terraces, increased use of irrigation), applying different livestock feeding techniques, diversifying into non-farming activities, and temporary or permanent migration. The crop trait-based adaptation techniques coupled with appropriate agronomic management practices are key areas that are recommended for adaptation.

The concept of community-based ecosystem adaptation in rural areas of Ethiopia encompasses a wide range of strategies at local and landscape scales, enabling communities to address climate change in an effective way. It is envisioned that ecosystem-based adaptation interventions will be developed and implemented by community-based innovation platforms, and that they will be a component of a broader adaptation strategy that includes education, training, raising awareness, and the development of early warning systems and technology measures as required.

**Existing and Potential Adaptation Measures:** A wide range of no and low regret adaptation options that are thought to reduce agriculture's vulnerability to climate change in Ethiopia are proposed by several researchers and organizations. These adaptation options were compiled and detailed mainly by the National Adaptation Program of Action (NAPA) and later updated by the Ethiopian Program of Adaptation to Climate Change (EPACC, which replaced NAPA). No and low regret adaptation options strengthen resilience to current variability and accommodate additional variability, emerging



climate trends/change. Most of the strategies are existing practices or parts of existing policies, and many of them have multiple benefits by increasing productivity and natural resource protection. The EPACC asserts that most of these adaptation measures in the agriculture sector can provide net benefits regardless of climate change and in real terms are no or low regret measures which are already rationalized under current climate. The EPACC stresses for the need to revitalize and maximize the benefits of these measures by improving and integrating steps of climate proofing to successfully achieve a full-fledged climate change adaptation in the agriculture sector. EPACC suggests comprehensive strategies for the success of adaptation in the agriculture sector. Included are climate monitoring and forecast based agro-advisories (agroweather advisory for short), food security programs, social welfare programs, integrated pest and disease management, efficient central-local coordination and harmonization, robust institutional capacity at the local level, and mainstreaming of climate change adaptation into core development policies. The country's Climate Resilience Strategy as part of building Climate Resilient Green Economy identified about 40 promising options through a long process of review and evaluation. It grouped these options into three strategic areas 1) Capacity building and cross-cutting activities that establish the capacity for managing change and sectoral resilience 2) Building on existing good practices in the agricultural sector 3) Protecting the most vulnerable in Disaster Risk Management and Food Security.


**Pillars of Adaptation Strategies:** A study carried out by the World Bank (2010) among households in rural Ethiopia identifies climate change adaptation options in geographic and social zones. Among these, the strategies directly related to agriculture in the central, northern and western highlands are listed as: 1) Land conservation and biodiversity 2) Access to agricultural technology, financing and markets, 3) Income diversification and agro-industry, 4) Irrigation and water harvesting. The Bank proposes increasing irrigated cropland and investment in agricultural research and development as the two pillars of national adaptation strategies in agriculture. These two pillars of adaptation strategies are meant to capture key aspects of a strategy capable of tackling the essential features of the climate of the future, i.e. an increase in temperature and changes in precipitation patterns.



**Biodiversity/Agronomic Management and Adaptation:** Ethiopia has a rich biodiversity containing valuable genetic resources for tolerance to shocks of temperature extremes, drought, flooding, pests and diseases. Preservation of these genetic resources is essential in developing resilience of plants and animals to shocks. Also general improvements in agronomic management practices can improve agricultural production and help address climate change. Irrigation is one of the main adaptation options identified and quantified in impact modelling assessments of climate change. Studies in Ethiopia also report irrigation having a doubling effect on net gross margin for farmers. Due to this and other socioeconomic reasons, the government (Agricultural Growth Project) has focused on the development of small-scale irrigation so as to increase productivity and reduce the impacts of climatic variability and change.

**Livestock and Climate Change Adaptation:** Livestock keepers have traditionally adapted to various environmental and climatic changes by building on their in-depth indigenous knowledge of the environment in which they live. However, the increasing human population, urbanization and land degradation have rendered some of those coping mechanisms ineffective. Different actions or approaches are recommended to combat the effect of climate change on livestock production in mixed crop-livestock system such as the use of adapted farm animal genetic resources, improve feed and feeding system, herd diversification and production system adjustment or intensification. Animal mix diversification has the potential to decrease the vulnerability of the herd to climate change, depending on the livestock species chosen. There are differences among livestock species in their ability to produce under given climate change (World Bank, 2011). Small animals including sheep, goats, and poultry can easily adapt to situations of feed shortage, however, the economics of herd diversification, for example from cattle to small ruminant or poultry depends on the relative costs of different species and relative revenues, both under current and future climate scenarios.

**Climate Resilience and Subsistence Agriculture:** Experience shows that agro-ecosystem based adaptation (community-based ecosystem adaptation) through innovation platforms have significant potential for building climate resilience among subsistence agriculture communities. Such form of



adaptation takes diverse biophysical conditions, socio-economic factors and agro-ecosystems of localities into account so as to design diverse strategies most appropriate to the specific localities.

## 6.5. Climate Change Mitigation in Ethiopian Agriculture

Mitigation is an action or a series of actions taken to reduce greenhouse gases (GHGs) emission to the atmosphere, which leads to global warming and thereby resulting in climate change. The causes of climate change associated with greenhouse gas (GHG) emissions are either natural or human induced or both. The mitigation actions considered here relate to the human induced actions. The human induced causes for climate change related to agriculture could be associated with the production of crops and livestock, and the management of natural resources.

**Greenhouse Gas Emission and Ethiopia:** Ethiopia's current contribution to the global increase in GHG emissions has been insignificant. The country's total emissions of around 150 Mt CO<sub>2</sub>e represent less than 0.3% of global emissions (CRGE 2011) which come from agriculture, industry, transport and construction. It is reported that agriculture and agriculture-related activities such as forestry are the main contributors. In terms of amount, agriculture consisting of crop production and animal production represent 50 % of the emission while forestry results in the emission of 37 % of the total amount (CRGE, 2011).

**Lower-Emitting Techniques:** If expansion of land for cultivation can be curtailed by improving crop productivity by using higher yielding varieties, use of fertilizers, and improved cultural practices, the saved land would serve as a good carbon sink. Emissions from crops are set to grow rapidly over the next 20 years due to low carbon crop residue and tillage management practices, and the increasing usage of organic fertilizers. Synthetic fertilizers can also be used, but their methods of applications need to be improved. The introduction of lower-emitting techniques for agriculture offers an opportunity to check this increase of emission, while maintaining production levels. This initiative includes improved agronomic practices that increase soil carbon storage, nutrient management to more efficiently use carbon/nitrogen, improved tillage and soil management, integrated mixed crop-




livestock systems, irrigation, intercropping, terracing, and other water-harvesting techniques.

**Mitigation Practices:** Soil disturbance tends to hasten decomposition and erosion whereas reduced tillage results in soil carbon gain and reduction of CO<sub>2</sub> emissions. To achieve the latter effect, conservation agriculture should be promoted, including the use of zero and minimum tillage. The obvious mitigation practices that need to be considered in this respect are a) minimize unnecessary clearing of forest lands and maintain grass lands in their natural state b) afforestation of cleared lands, particularly in areas of steep slopes, has been a major undertaking of the public private sector over the last four or so decades. Despite such encouraging efforts, land clearing far outstrips land rehabilitation at the present moment.

**Mitigation through Agroforestry:** Afforestation/reforestation efforts have been under implementation in the last five decades but the rate at which it was progressing was not in balance with the rate of deforestation. Perennial trees and shrubs that give the highland mixed agricultural system its evergreen character provide multiple supports to the agricultural system. The trees enrich soil carbon, reduce erosion and improve overall soil fertility that sustains agricultural productivity. Agroforestry systems are increasingly recognized as important for the provision of both climate change mitigation and adaptation services. Recognizing this, the New Partnership for African Development (NEPAD) of the African Union Commission have called for the scaling up of agroforestry as a critical land use practice that can increase both current and future productivity under the specter of climate change.

**Livestock and GHG Emission:** Among the livestock species, cattle are the major contributors to GHG emission in Ethiopia. In a business-as-usual scenario, emissions from livestock are projected to increase as a function of livestock population growth, mainly driven by an increase in methane from enteric fermentation and manure management. Application of improved livestock technology and management will increase the efficiency of production. These techniques inevitably lead to culling unproductive animals and reduce headcount which gives chance to farmers shifting to better management of fewer productive animals and reducing GHG emission from livestock. Partial replacements of cattle with lower emitting species (poultry, sheep and goat,





fish) would be an alternative option for mitigation of GHG emission from livestock. These low-emitting animals are high feed converters and low GHG emitters as compared to large ruminants such as cattle (IPCC, 2006).

**Mechanical Equipment and CC Mitigation:** Under the Ethiopian context, draught animals are the main source of plowing, cultivation, harvesting, threshing. The introduction of mechanical equipment (e.g., tractors including 2-wheel tractors) for plowing/tillage to fully or partially substitute oxen among farmers in highland area is an alternative options for adaptation and mitigation of climate change.

**AGRICULTURE AND FOOD SECURITY  
SUB-WORKING GROUP  
PASTORAL AND AGRO-PASTORAL SYSTEM**

## 7. Pastoralism in Ethiopia

### 7.1. Production, trade and mobility

Pastoral households are frequently defined as those in which more than 50 per cent of total household income comes from livestock related activities (Swift 1984). Not all pastoralists will maintain the same mix of livestock—camels, cattle, sheep, goats and donkeys—some keep more camels while others herd more cattle. The precise mix of livestock kept is dependent on rainfall, soils, topography, access to water, livestock diseases,<sup>14</sup> family size and wealth. In slightly wetter, flatter and more productive rangelands pastoralists will tend to herd more cattle; while in the drier, sandier and hotter rangelands pastoralists will herd more camels and goats. Whatever the animal species, pastoralist livestock convert rangeland plants that cannot be consumed by human populations into high quality animal protein that can be both consumed and sold. The pastoralist's strategy of mobile livestock production enables human populations to occupy areas of the Horn of Africa that would normally be impossible to occupy.

Pastoralism is not specific to the Horn of Africa. Pastoral communities are found throughout the arid and semi-arid areas of sub-Saharan Africa, the intensely cold grasslands of central and northern Asia and northern Europe, and the world's high mountain grasslands. An estimated 25 per cent of the world's land surface is under pastoralist production (de Jode 2014); whilst the pastoralist population in Africa is estimated at 268 million (over a quarter of the total population), living on 43 per cent of the continent's total land mass (African Union, 2010).

Ethiopia's pastoral population—one of the largest in the world—is estimated to be 15 per cent of the country's total, or an estimated 14 million people; including the majority of the population in Somali and Afar Regions and 10 per cent of Oromiya Region (the Borana and Karrayu pastoralists) as well as areas of the Southern Nations, Nationalities and Peoples, Gambella and Beni Shangul Gumuz Regions (Yacob, 2000; Sandford and Habtu, 2000). Pastoralists are found in 124 districts or woredas, in 21 zones and 7 regions.

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<sup>14</sup> Tsetse fly infestation is also a major threat in the high potential grazing areas of Western and South Western rangelands including Benshangul Gumuz, Gambella and SNNP regions




Pastoralists inhabit the arid and semi-arid rangelands that account for 65 per cent of the national landmass of Ethiopia (see Figure 1). These rangelands are typically below 1,500m, with average annual rainfall of between 100 to 700mm.



**Figure 1: Location of pastoral rangelands in Ethiopia**

Pastoral communities in different regions not only herd different livestock species, but in many cases diversify their livelihoods further to include seasonal cropping in riverine areas or low-lying areas that benefit from run-off. Agro-pastoralists will prioritise crops that are suited to the arid and semi-arid rangelands—including millet, sorghum, maize and pulses (cowpea and pigeon pea). These crops are consumed within the household and sold in local markets.

Pastoral and agro-pastoral livelihoods are dominated by families (a man or several brothers, their wives and children, and other close relatives including aged parents and other family members), who will live in close proximity and share herding and watering duties. The families come together seasonally to herd their animals far away from the home-area to exploit grazing and water sources. These seasonal movements of livestock depend on families working



well together and supporting each other in difficult times. As a result, pastoralists have some of the most complex and rich forms of reciprocal social insurance and welfare systems in the world. These systems have assisted pastoralists to recover from droughts, livestock disease and livestock lost to raiding through the gifting of food, labour and livestock (Tache and Sjaastad, 2010).

## **7.2. Livelihoods, wealth and poverty**

Livelihoods have been described as: the ‘assets’—natural, physical, human, financial and social; the ‘activities’; and the ‘access to the assets’—mediated by institutions and social relations; that together determine the living that can be gained by the individual or household (Ellis, 2000). The set of five assets embraced in this definition forms the core of the conceptual model, ‘the livelihood analysis framework,’ developed in the late 1990s. In pastoral areas the main livelihood assets are natural (rangelands, pasture, water and trees), financial (livestock), and social (the reciprocal social relationships mentioned above). Significantly, social networks are maintained and strengthened through the gifting and receiving of livestock and livestock products, and therefore livestock play a central role in maintaining social assets. Human assets that include schooling, education and indigenous knowledge, have typically been weaker in the formal sphere, although indigenous knowledge systems are typically very strong. In contrast, physical assets including infrastructure have been limiting in pastoral areas (Pavanello, 2009). Four main livelihood systems have been identified in Ethiopia’s pastoral regions: pastoralism, agro-pastoralism, irrigated agriculture and settled urban. Each livelihood is a rationale response to a range of factors that includes (amongst others) livestock holdings, rangeland management systems, population increase, risks and perceived risks, and local government and national policies.

As mentioned, the Horn of Africa is undergoing a process of intense change, the result of which is a range of new factors impacting pastoralists and agro-pastoralists; including the development of nation states and (in stable countries) new forms of administration, infrastructure and services, and impressive economic growth rates. Rapid change is also the result of the doubling of pastoral populations. There are also changes in land-use, with

former pastoral rangelands now annexed for agriculture, irrigation, national parks and urban development. In some pastoral areas, rangelands have been lost to alien species—*Prosopis juliflora*, *Parthenium hysterophorus* and *Acacia drepanolobium*. The result of these land losses, in particular where the losses have involved key grazing areas that play an important roles in maintaining livestock in times of drought, has been a reduced level of livestock mobility and rising vulnerable to drought. In some cases family livestock holdings have collapsed and a destitute class has emerged that is dependent on government support.

As a result of these and other related changes, pastoral livelihoods are now in a state of flux.

It is no longer possible to equate the wellbeing of households in pastoral areas with the numbers of livestock that they herd. While livestock keeping may be an important for some pastoral households—with livestock continuing to provide food, income (the sale of surplus male animals and milk, butter and other livestock products), 'savings' against shocks and maintaining social networks—for others livestock ownership is now a fringe activity. Those that have moved out of pastoralism include both very wealthy households (that have 'cashed in' some of their livestock resources to establish themselves in business or to educate their children, and are now engaged in the business or service sectors) but also the very poor. The very poor have invariably lost their livestock to drought or related shocks, and have moved to the towns to enrol in government programmes including the Productive Safety Net Program (PSNP).

Some pastoralists that have transitioned out of pastoralism have moved well beyond Ethiopia's borders, and are settled in other countries of Africa and indeed the rest of the world. These households now play an important role in remittance payments; which it is estimated are a considerably larger contribution in the pastoral areas of the Horn of Africa than international development assistance, playing a crucial role in supporting livelihoods in the region.





### 7.3. The state of food security in Ethiopia's pastoral areas

As has been well documented, agriculture plays a central role in the lives and livelihoods of 80 per cent of Ethiopia's population (including smallholders, irrigated and peri-urban farmers, pastoralists and agro-pastoralists) as well as in the national economy. Agriculture contributes 45 per cent of GDP<sup>15</sup>. Despite the importance of agriculture, and impressive agricultural production and productivity gains over more than a year, Ethiopia remains one of the poorest countries in the world. High levels of rural poverty and stunting can be found in the most productive agriculture areas,<sup>16</sup> and in pastoral areas high levels of poverty and food insecurity exist.

Studies have also confirmed that access to family planning services has a fundamental impact on food security, poverty reduction, health improvement and indeed environmental sustainability (Rovin et al, 2013). This finding is also

supported by studies that confirm the link between addressing population growth and achieving long-term improved food security outcomes in the face of climate change (Scott and Smith, 2012). As family planning in Ethiopia's pastoral areas is low, it can be seen that it will be difficult to address long-term food security.

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<sup>15</sup> <http://www.ethiopia.gov.et/web/Pages/Economy>

<sup>16</sup> Poverty and stunting levels are as high if not higher in Ethiopia's highland smaller farming areas, including the 'high potential areas' that generate surpluses.

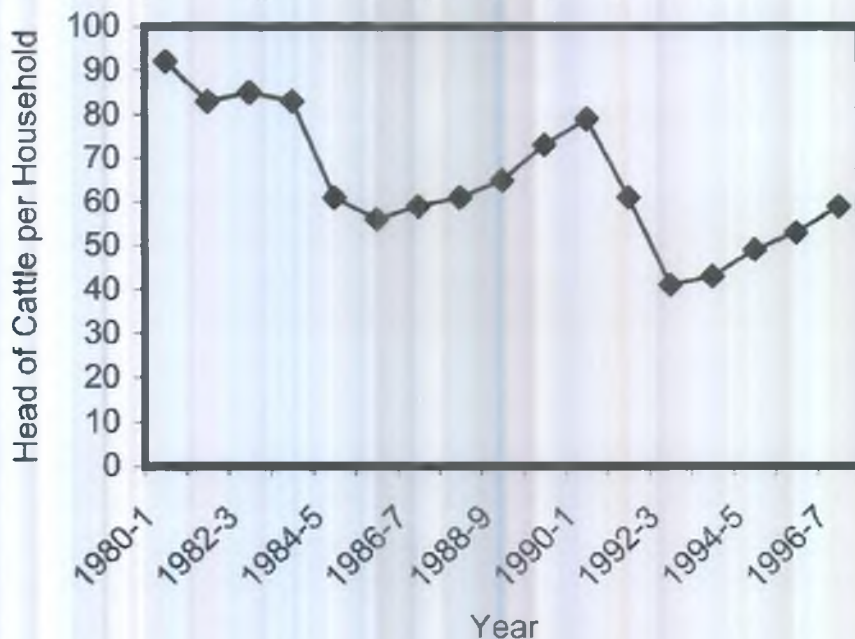
## **8. Trends and impacts**

While there is little hard scientific evidence to confirm climate change trends in the pastoral areas of the Horn of Africa, pastoralists are clear that weather patterns are more variable than in the past and that the pastoral areas are experiencing more extreme weather events, including more intense rainstorms and more droughts. While local perceptions provide valuable empirical information, it should be noted that droughts are an integral part of life in Africa's arid and semi-arid lands, and that droughts have been recorded over several hundred years: There were major droughts in the 1960s, 1970s and 1980s, and most recently the Horn of Africa drought in 2011.

Some researchers suggest that drought cycles are shortening, and this may be true, but whether this is the result of climate change, or long-term weather cycles, is not clear. What is however clear is that the combination of weather events, a doubling of pastoral populations, the loss of prime dry/drought season grazing, reduced mobility and a substantial increase in the number of poor and very poor pastoral households, are resulting in levels of resilience to drought being much reduced. A single rain failure can now trigger a local livelihood crisis, when in the past most pastoralists were able to withstand two seasonal rain failures. As livelihood coping strategies have been eroded, levels of weather-related vulnerability and dependence on external assistance have increased. As a result, some pastoralists are trapped in a 'permanent livelihood crisis' (Cossins, 1988; Coppock, 1994; Bassi, 2002; Devereux, 2006).

### **8.1. Variability, drought and livestock**

Pastoral livestock production systems are typically mobile, multiple-species and managed flexibly. Different animal types are herded in different ways in order to be able to accumulate larger herds, and therefore establish a larger buffer to better withstand environmental shocks (Dahl and Hjort 1976; Sandford, 1983; Krätli, 2001). In extended dry seasons, or times of drought, the availability of pasture and water is restricted and livestock have to walk further each day. As the quality of pasture is reduced the animals are weakened (Tibebu, 2013). If the drought persists, milk production will decline and may stop completely. As the animals lose body condition, so their value falls. Pregnant animals may also abort; and even if pregnancies



**Figure 2:** Trends in cattle holding per household among Borana pastoralists

Much of the information available on livestock losses to drought is anecdotal; however there are studies that provide information from Borana. Here it is estimated that the 1983-5 drought resulted in the loss of 37 per cent of cattle (Desta and Coppock, 2002). The same study notes that cattle numbers recovered to about 85 per cent of the previous numbers by 1990, when another drought resulted in a second loss of 42 per cent. In the period 1980 to 1997 average cattle holdings per household declined by from 92 to 58 cattle per household. The accumulated impact of these droughts resulted in a downward shift in wealth status for more than 50 per cent of the herder sampled, with in the same period only 7 per cent of Borana herders reporting an increase in livestock holdings (see Table 1). A second Borana study reports that more than half of the cattle were lost again in the drought of 1989-1999 (Shibru, 2001).



Table 1: Wealth status shifts reported by 317 Borana pastoral households


Current wealth status	Past wealth status		
	Wealthy	Middle class	Poor
Wealthy (24)	22	1	1
Middle Class (132)	56	58	18
Poor (161)	29	73	59

Efforts have been made to quantify the value of livestock losses to drought. Desta and Coppock, (2004) estimated that in a 17 year period from 1980 to 1987 that the average loss of livestock to drought was USD 6,523 or USD 893 per person. Extrapolated to 7,000 households in the study area, the total wealth loss is USD 46 million and more than USD 300 million for the entire Borana Plateau.

While the trends outlined here are not in doubt, it is important to note that pastoralists will not give detailed and accurate information on either livestock holdings or drought related mortality, and they only offer indicative figures. Furthermore, the annual rate of human population in the Borana pastoral area was estimated to be 1.3 per cent in the 1960s but this has escalated to over 2.5 per cent in the late 1980s, with the result that human population has doubled in the period 1980 to 2000. Human population increase and the increase in the number of households is therefore a factor in the reduction of livestock holdings, as the area of rangeland managed by the Borana shrank during this same period (Coppock, 1994; Desta and Coppock, 2004; Berhanu, 2011a). More research is therefore required in this area.

### **Drought and gender**

There has been a general lack of detailed information regarding pastoral women, although this has begun to change in more recent years. Pastoral women are responsible for a diversity of roles, including caring for children and older household members, livestock herding—in particular young-stock and sick animals—house construction, household food security, food preparation, collecting water, and collecting firewood (Akilu A et al, 2013). Devereux (2006) reports pastoral women in Somali Region have higher mortality rates and lower life expectancy. Ongoro and Ogara (2012) suggest



pastoral women also are more vulnerable to drought, and certainly that their work burden increases significantly. Pastoral women are therefore potentially more vulnerable to climate change.

### **Drought and terms of trade**

Drought has three phases in relation to trade. The first phase involves a decline in the availability of milk. As the availability of milk decreases, pastoral households purchase additional grain as a replacement. While grains are rich in calories they are typically low in protein, with the result that the quality of diet suffers. In the second phase, milk is no longer available and pastoralists become completely dependent on grains. During this phase traders tend to inflate the price of grains, with the result that household food availability is affected and household members are required to miss meals. During this phase the price of livestock also tends to fall, with the result that the terms of trade between cereals and livestock worsens for pastoralists but improves for both grain and livestock traders. Livestock off-take commonly increases in this second phase of drought. Finally, the third phase involves the rapid deterioration in livestock body condition, with the result that sales of livestock collapse as traders are less and less interested. In this phase grain prices can double and triple as traders exploit the need for the steady rise in demand. It is in this third phase that pastoralists are particularly dependent on government support, both through the stabilization of grain prices and market support to remove surplus livestock through commercial and slaughter destocking (LEGS, 2009).

## **8.2. Other changes in pastoralist areas**

### **Loss of biological diversity**

In the same way that there are profound changes taking place in human populations in the rangelands, there are major changes taking place in plant populations. Perhaps the most significant change is that over the last 40 years there has been a decline in palatable grass species—*Chrysopogon plumulosus*, *Cenchrus ciliaris* and *Setaria macro melena*—and an increase in woody browse species that are less palatable to livestock and result in a loss of productivity (Thornton et al., 2007). There has also been a loss of indigenous trees—*Acacia tortilis*, *A. senegal* and *A. nilotica*—the pods of



which provide an important feed source for livestock. These changes are the result of a range of factors, including increased grazing pressure and reduced mobility (livestock are now grazing some areas throughout the year) and a substantial increase in charcoal production. In addition to these generic changes the rangelands have also been affected by the introduction of exotic plant species, such as *Prosopis juliflora*—a thorny shrub—which now dominates over 1.5 million ha of Afar and is also present in large areas of Somali and Oromia Regions.

### **Variability and agro-pastoralism**

As mentioned, Ethiopia is home to many agro-pastoralists for whom cropping is an important seasonal activity. Agro-pastoralists in the riverine areas of the Awash (Afar Region) and Gode, Kelafo and Dolo Ado (Somali Region) are primarily involved in irrigated agriculture, while others are dependent on seasonal rains. The major crops that are cultivated under rain-fed systems include sorghum, teff, sesame, groundnuts and maize, while under irrigation the main crops that are grown are maize, fruits and vegetables.

Yields are strongly linked with water availability, and therefore yields in rain-fed systems are very variable. In some years when rainfall is above normal, cropping provides a useful source of food. In contrast, crop failures are associated with years of below normal rainfall; and also with years when the rains started, then stopped, and then resumed again but too late to stop the crop wilting and dying (Howden, et al 2007). There is also mounting evidence that an increase in temperature associated with climate change results in lower yields. By contrast, maize yields under irrigation are commonly around 3.6mt per hectare in Afar while yields of 2.9mt per hectare have been recorded in Somali Region as a result of poorer soil fertility.

Whether it is the result of weather and climate change, or other factors including an increase in human populations and a squeezing of household holdings, a study carried out by Solomon (2011) in the Meiso agro-pastoral areas confirms a marked reduction in the diversity of crops being planted since 1966 (see Table 2). As temperature increases and rainfall is forecast to drop, it can be expected that the diversity of cropping will continue to decrease with crops including maize replaced by crops more suited to drier environments such as sorghum and millet (Yamori et al. 2013).



**Table 2:** Diversity of crops grown by farmers at Meiso over the last 50 years

Period	Maximum	Minimum	Mean
1966-1980	10	2	5
1981-2000	10+++	1	4
2001-2007	5++	1	3
2008 - 2011	4***	1*	2

Key: \* sorghum (*Sorghum bicolor*) \*\*\* sorghum with maize (*Zea mays*) and soybean  
 + all the above with sesame ++ all the above with tef  
 +++ all the above with linseed or cowpea

Solomon (2011) also interviewed agro-pastoralists about their perceptions of climate change and the impact that it would have on seasonal cropping. As can be seen in Table 3 below, agro-pastoralists identified a range of different factors, including amongst others crop failure, new patterns of diseases and weed species. They also ranked the impact on feed availability and access to water.

**Table 3:** Agro-pastoralists perception to climate change impacts in Meiso Woreda, Oromia Region

Vulnerability Factor	Ranking	
	%	
	Serious	Very Serious
Frequent total crop failure	4.0	96.0
New pattern of disease and pest	4.0	96.0
Appearance of new weed species	42.7	57.3
Shortage of feed for animals	5.3	94.7
Water shortage	25.3	74.7
Loss of biodiversity	9.3	90.6
Increase of soil degradation	48.0	52.0

### 8.3. Climate change forecasts and impacts

Looking to the future, the IPCC report (2007) forecasts that climate change will have a profound impact on agricultural production in sub-Saharan Africa as levels of investment in adaptation are as yet relatively low, and levels of



poverty and vulnerability are already amongst the highest in the world. It is estimated that temperatures will rise by as much as 1.6°C by 2050 in the semi-arid parts of Southern Africa, and as much as 2.6°C in Afar and Somali Regions. (Cairns et al., 2013). Average forecast temperature increases in Ethiopia are between 0.9-1.1°C by 2030, 1.7-2.1°C by 2050 and 2.7-3.4°C by 2080 (Kefyalew and Tegegn, 2012).

Forecast changes in precipitation however vary between different climate change models. Cairns et al, (2013) suggest rainfall in East Africa would increase by 6 per cent March to May, and 4 per cent June and August. As the main rains in the pastoral areas of southern Ethiopia fall between March and May it would seem the pastoral areas may well benefit. This said, Hellin et al., (2012) report that changes in precipitation patterns may result in more short-term crop failure and also long-term declines.

Mention has been made that pastoralism is a proven, adaptive livelihood system that supports human populations to inhabit one of the most remote and inhospitable regions of the world, including in remote areas that cannot access rivers and therefore benefit from irrigation. For this reason, mobile pastoralism is likely to continue for the foreseeable future as the main livelihood system as there is simply no viable alternative (Hesse and Cotula, 2006; Little, et al., 2010). As also mentioned, pastoralism offers a viable livelihood for some but as the result of increasing pressures on the rangelands and future drought events, many households will continue to transition to other livelihoods. This process can, and is, being supported by the improvement of service delivery in pastoral areas—education, health, markets and water—that attracts more and more vulnerable households with few livestock, or those households recently affected by drought (DFID, 2009). Once established, high growth rates of the settled population will also be a major force for development and expansion.

### **Impact on settlements**

It is not at all clear what long-term impact climate change will play in the development of market towns in pastoral areas. For example, as the populations of market towns grow, so too will their demand for services including water. In some pastoral areas water can be accessed from rivers or ground-water, while in others access to water is more problematic and

populations are dependent on the harvesting and storage of rainwater (birkads in Somali Region). While this approach to water provision may serve local populations well in years of above average rainfall, in other years, including drought years, water shortages can be expected to become increasingly problematic (IFAD, 2009).

### **Impact on livestock and rangeland**

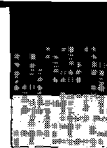
Rangeland productivity may also be adversely affected as a result of increases in temperatures and carbon dioxide levels. For example, some plants (known as C4 plants) are expected to do better from rising carbon dioxide levels while other plant species (known as C3 plants) are expected to do less well (Yamori et al., 2014). Overall however, changes in rangeland productivity will be determined by rainfall, as this is the key constraining factor to plant growth in the arid and semi-arid lands.

Livestock productivity may be affected by a range of factors, including vector borne diseases that spread to new areas as the result of temperature and humidity changes. Similarly, the combined result of climate change, and the general deterioration of the management of the rangelands and increases in woody browse, can be expected to result in an increasing number of pastoralists maintaining mixed herds of browsing animals—camels and goats— with smaller numbers of cattle and sheep (Kefyalew and Tegegn, 2012).

### **Impact on cropping in agro-pastoral areas**

Zerihun and Kelbore (2012) studied the impact of climate change on crop yields in Ethiopia, and forecast that the increase in temperatures will negatively affect crop production as plant physiological, bio-chemical and molecular processes become affected, particularly in the lowland and hotter pastoral areas (see Table 4).





**Table 4:** Percentage change in mean crop yields at regional and national level

2050				2100		
Region	Teff	Wheat	Maize	Teff	Wheat	Maize
Oromia	-3.58	-7.26	-1.51	-1.62	-9.59	0.18
Amhara	-1.93	-0.19	47.86	-0.66	-12.30	-0.21
SNNPR	1.89	-17.04	-3.09	-0.28	-17.23	-8.19
National	-2.43	-6.21	10.84	-1.09	-11.03	-1.14

In addition, Adunga et al., (2013) studied agro-pastoralists and dryland farmer perceptions to changes in weather and climate, and found that the most commonly associated changes included rainfall, including untimely rainfall, and livestock diseases (see Table 5).

**Table 5:** Farmers perceptions of changing vulnerability to climate change in Eastern Ethiopia

Perception variable	Frequency	Percentage
Precipitation	234	71
Change in temperature	182	55
Untimely rain	209	63
Drought	141	43
Flood	151	46
Livestock disease	265	80
Land degradation	144	44
Decreasing crop yield	212	64

## 9. Vulnerability of pastoralists to climate change

### 9.1. Strategic and induced vulnerability

There is a general consensus that pastoral and agro-pastoral communities in the Horn of Africa are facing rising levels of vulnerability. This is the result of a wide range of factors that have been outlined already—exponential population growth, rangeland fragmentation, changes in rangeland management, the invasion of exotic species, conflict, and inappropriate rangeland management policies (Pavanello, 2009). Patti, et al. (2012) carried out a household-level baseline survey in Borana, and another 5 sites in the East Africa region, and reported that pastoralists and smallholders in these areas recognise multiple drivers of change, and that climate change was identified as one a several key drivers.

Krätli et al., (2013) have classified pastoral vulnerability as both 'strategic' and 'induced.' Strategic or 'baseline' vulnerability refers to the degree of vulnerability inherent in a pastoral system. By contrast, 'induced vulnerability or 'unnecessary and dysfunctional vulnerability' refers to the unexpected or cumulative loss of capacity to maintain the system as the result of structural shifts triggered by external shocks and internal adjustments. This latter form of vulnerability is thought by some researchers to be directly related to pastoralists' capacity to maintain their traditional livestock production strategies including mobility. Krätli et al., go on to argue that it is quite common for outsiders to erroneously put blame for pastoral crises on 'strategic vulnerability' when in fact it should be attributable to 'induced' vulnerability. Areas of misunderstanding include political marginalisation, land alienation, policy and programme interventions, environmental degradation, infrastructure, limited livelihood options and human population growth (Riché et al., 2009).

A range of factors that are external to the pastoral system, including poorly formulated pastoral area policy, has exacerbated pastoral vulnerability (Devereux, 2006, 2010; Pavanello, 2009). Policy makers with limited knowledge and understanding of pastoral production systems have tended to shape policy (Gadamu, 1990; Markakis, 1993; 2000; Bassi 2002; Pavanello, 2009; Berhanu, 2011b). And as a result, the general development trend has

been to promote sedentary agriculture as an alternative to mobile livestock keeping, in particular through the development of irrigated agriculture. Not all irrigation schemes have been targeted to benefit the local pastoral population, and at times this has resulted in tensions between large-scale commercial agriculture and the pastoralists that see no direct livelihood benefits (Muller-Mahn et al. 2010; Elias and Abdi, 2010; Behnke and Kerven, 2011). Ironically, other pastoral area policies are characterised by ambitious plans for the commercialisation of livestock and a planned increase in exports. The result of these policies has included huge investment in water resource development and the dislocation of former tried and tested rangeland management systems. The outcomes may have increased livestock off-take but have also resulted in undesirable environmental outcomes, and an erosion of indigenous knowledge systems and institutions (Coppock, 1994).


Vulnerability has also exacerbated conflict, including inter-ethnic clashes fuelled by the fragmentation and deterioration of the rangelands. Such conflicts have resulted in the loss of life, displacement of human populations and the loss of livelihood assets including livestock (Said, 1997; Devereux, 2006; Rettberg, 2010; Elias and Abdi, 2010).

## **9.2. Vulnerability specific to climate change**

Vulnerability to climate change is a function of: the magnitude, character and rate of climate change; the sensitivity of the system; and the adaptive capacity of the system to change, to moderate or cope with the impacts, and to take advantages of the opportunities (IPCC, 2007). More recent definitions conceptualise vulnerability as the interaction between exposure, sensitivity and adaptive capacity (Chhinh and Poch, 2012). Using these latest definitions, exposure refers to the degree to which a system is exposed to climate change and the nature of the climate stimulus; while sensitivity is the degree to which a system is affected—whether positively or negatively—by extreme weather conditions and associated climatic variations. Adaptive capacity describes the ability of a system to adjust to actual or expected climate impacts, or to cope with the consequences of climate change.

Adaptive capacity is affected by a range of factors include household wealth, access to and use of technology, availability of infrastructure and institutions,





potential for irrigation and literacy rates. Wealth enables communities to absorb and recover from losses more quickly. For example, the number of livestock owned, key assets (radios, refrigerators) and the quality of the main home, are commonly used indicators for wealth in rural areas, as is proximity to agricultural input supplies. Institutions and infrastructure also play an important adaptive role.

At any point in time, the greater the exposure the higher the vulnerability (Riche et al. 2009). Vulnerability is reduced however when the sensitivity of the system is minimised. Sensitivity decreases or increases over time due to adaptable measures taken following disaster(s). Chhinh and Poch (2012) suggested that poverty reflects the present deprivation while vulnerability reflects future household prospects.

### **9.3. Pastoralism, vulnerability and climate change**

In the future, vulnerability analysis in pastoral areas will need to recognize climate change as it is expected to result in an increase in levels of vulnerability unless communities can adapt (Hesse and Cotuia, 2006; Birch and Grahn 2007).

There are relatively few studies that examine climate trends data in Ethiopia's pastoral areas. However, Berhanu and Beyene (2014) documented temperature and rainfall trends in southern Ethiopia's rangelands over the last 50 years (Figures 3 and 4). As can be seen, the researchers report that temperatures are on the increase and rainfall on the decrease. In addition, Berhanu and Beyene point out that rainfall is becoming more erratic.

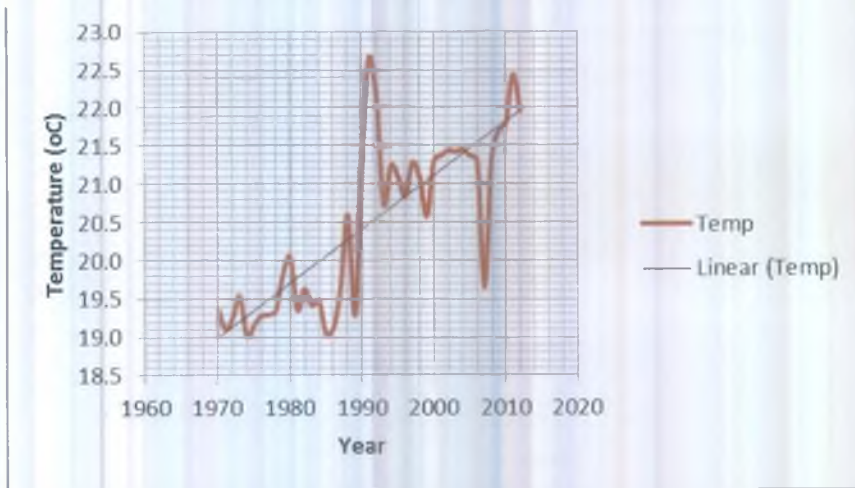


Figure 3: Nagelle station long-term average annual temperature trends

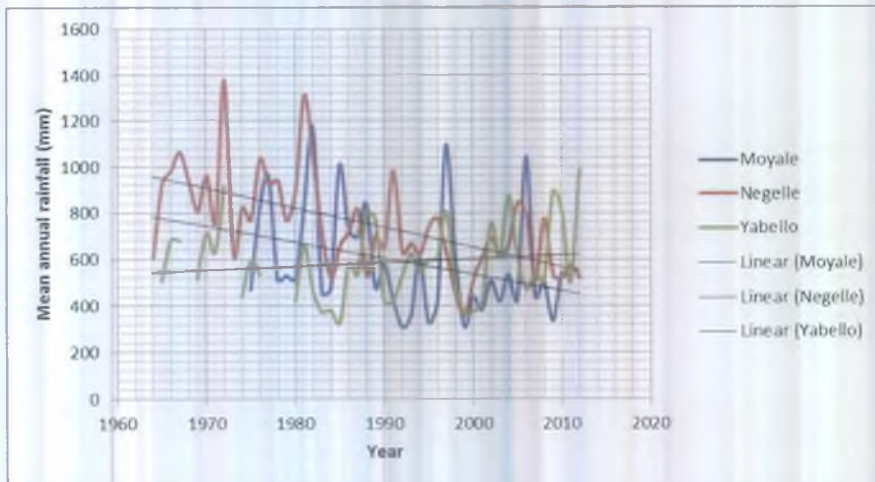


Figure 4: Trends in mean annual rainfall in three major stations

There is relatively little published information on climate-induced pastoral household vulnerability in Ethiopia, but Stephen Devereux carried out one of the most cited studies (Devereux, 2006). The study covered the following

areas: the Somali Bantu of Kelafo; irrigated farming on the Wabe Shebele and Genale/Dawa; agro-pastoralists in Jijiga; and pastoralists in these areas. The study found that farmers using irrigation in Kelafo have the highest income as they supply vegetables to Somalia. The study also found that pastoralists in all areas had experienced cyclical drought, and that as a result some households had abandoned pastoralism and moved to market towns in particular those associated with irrigation. Interviewees also reported other hazards including flooding along the river side, crop disease and pests, livestock disease, market disruption, insecurity and conflicts, environmental degradation, poor infrastructure, high cost of commodities and migration, as major causes of vulnerability.

The result of a range of factors including climate variability and extreme weather events, the study report includes a self-assessment that the proportion of households 'doing-well' dramatically declined from 90 per cent in the mid-1990s to about 30 per cent in the mid-2000s (Devereux, 2006, p.87) (see figure 5).

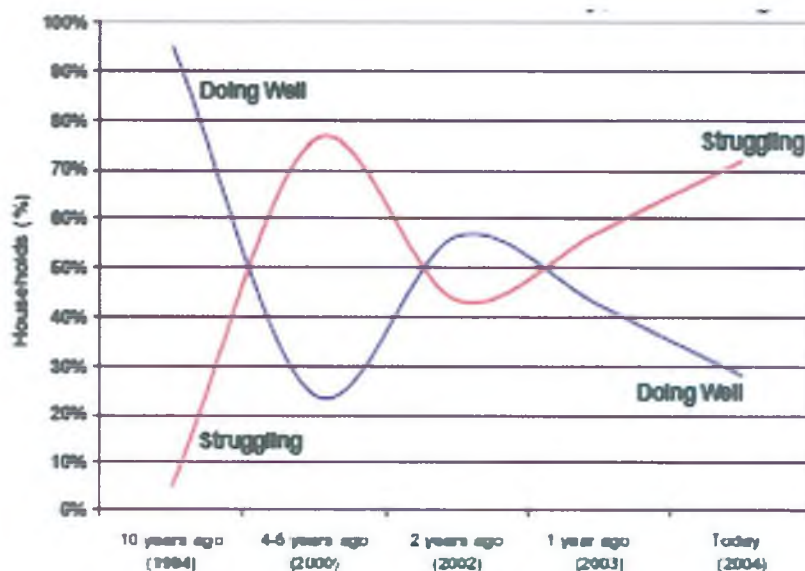


Figure 5: Trends in self-assessed vulnerability, Somali Region



## 10. Pastoral and agro-pastoral adaptation responses

There are two major alternatives in the choices for adaption in pastoral and agro-pastoral areas. The first relates to adjustments in pastoral production practices and include increased pastoral mobility, herd splitting in times of extreme weather events, shifts in herd mixes to include more drought-tolerant camels and goats, and perhaps increased use of livestock feed supplementation (Berhanu and Beyene, 2014). Research carried out in Afar and Borana confirms that this form of adaptation continues to be important, as pastoralism remains a principal source of livelihood for many people (Berhanu et al., 2007; Tsegaye, et al., 2013).

The second adaptive alternative is livelihood diversification into options that are less dependent on livestock, and there are a number of studies that have been carried out in Ethiopia on this category (Desta and Coppock, 2004; Berhanu et al., 2007; Davis and Bennett, 2007; Beyene, 2012; Gebresenbet and Kefale, 2012; Tsegaye et al., 2013). These studies confirm that for poorer households alternative income generating activities include livestock trade, dryland farming, wage employment, artisanal mining, charcoal making and fuel wood collection.

In a study carried out in Borana (see Figure 6), out of the whole mix of activities it can be seen that dryland farming is the most important. The researchers suggest that only 10 per cent of households participated in the relatively high-return capital-intensive activities, with the remainder turning to mainly low-return activities (Berhanu et al., 2007; Beyene, 2012; and Berhanu and Beyene, 2014). The researchers go on to suggest that gender plays an important role and that pastoral women play the lead role in participation in non-pastoral activities, or between 51 and 77 per cent.

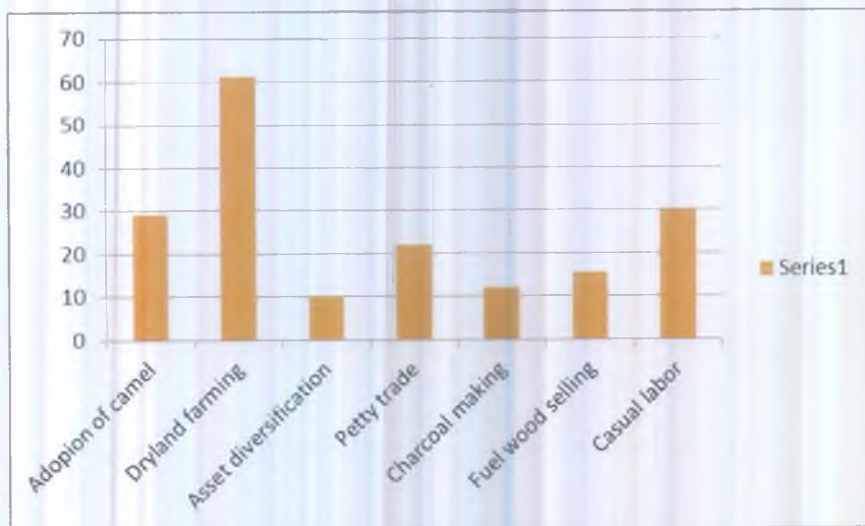


Figure 6: Nature of Pastoral household adaptation choice in Borana area (%)

### 10.1. Adaptation to variability and erratic weather events

Pastoralists have historically lived with variability, and erratic weather patterns and events, and for this reason they have been forced to adapt. Some researchers suggest that pastoralists have some of the highest levels of adaption of any human populations in the world. For example Riche, et al., (2009) found that pastoralists have tried and tested ways of avoiding heat stress. Somali pastoralists use water-soaked sacks to wrap around water jars to keep them cool. Borana pastoralists incorporate soil into the construction of their roofs as a form of insulation. The same researchers identified other strategies pastoralists use to manage extended dry seasons and drought: livestock diversification, feeding animals with tree branches, hay making, enclosing pasture for lactating cows, conserving water, digging deeper wells, preserving grains, collecting wild fruits, receiving food aid, migration and generating alternative income. Pastoral institutions in each of Ethiopia's pastoral areas were also found to be adept at peace building, conflict mitigation and resolution, resource sharing and migration—in particular during drought times.

## 10.2. Livestock production adaptation strategies

The Government of Ethiopia NAPA (2007) report identified a range of adaptation interventions that could potentially assist pastoralists to adapt to climate change. These include: additional care to avoid over-grazing and better manage stocking rates with pasture production; grazing with mixed herds of grazers and browsers; increased use of forage crops; water resource development; and the increased use of livestock feed supplementation. These recommendations are supported and expanded by IFAD (2009) and Thornton et al., (2007):

*Livestock management systems:* water and shade development; improvements in herd composition; destocking in times of drought.

*Production adjustment:* diversification of livestock species; intensification and/or integration of pasture management, livestock and crop production; changing land use and irrigation; altering the timing of operations; conservation of ecosystems; modifying stock distances and routing.

*Breeding strategy:* identifying and strengthening local breeds that have adapted to local climate stress and feed sources; improving local genetics through cross-breeding with heat and disease tolerant breeds.

*Market responses:* improved trade and credit schemes.

*Institutional and policy change:* the introduction of insurance and subsidy schemes.

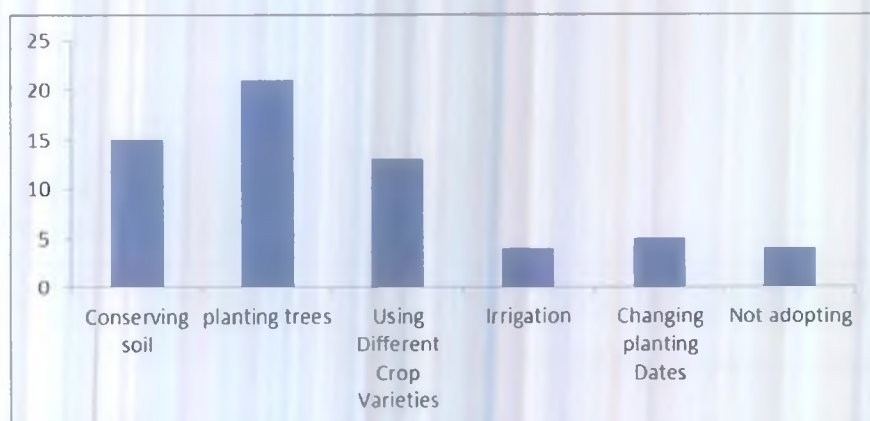
Feed shortage is one of the major livestock production constraints in the pastoral areas of the Horn of Africa and indeed in Ethiopia's highland farming systems. In some areas, pastoralists enclose and protect grazing areas for the dry season/ times of drought, while in other pastoral areas households will cut grass in the wet season to make hay that is stored for use in the dry season. Some of the areas that have been enclosed were in fact highly degraded areas that it has been possible to re-seed with *Aristida*, *Cenchrus*, *Chloris*, *Echinochloa*, *Eragrostis*, *Panicum*, *Pennisetum* and *Sporobolus*. Further improvements are possible with the introduction of indigenous and exotic grasses, legumes, and drought resistance trees that can increase the supply of forage material available to livestock. It will also become increasingly



important to conserve hay and promote improved management that can enable livestock to be moved between pastures to avoid over-grazing.

### 10.3. Dryland crop production adaptation strategies

Agro-pastoralists and irrigated farmers in pastoral areas can adopt a range of strategies to accelerate adaption. These are not necessarily new to all households but it is still rare to find households employing all the options available. For example, a study carried out by Temesgen et al. (2008) confirms that agro-pastoralists were involved in soil and water conservation, planting trees, planting new crops and varieties, irrigation and changing planting dates (See Figure 7).



**Figure 7:** New forms of adaptation to climate change

Increasingly it seems that agro-pastoralists and farmers are giving increased care to establishing optimum plant populations, weeding, and the use of fertilizer, as these help the crop to make best use of available water (Kidane and Bedru 2010; Getinet 2013; and Seme et al 2013). These communities also practice simple forms of soil and water conservation that can result in yield gains of between 50 and 100 per cent and an 80 per cent increase in straw yields.

Adugna, et al (2013) studied the practices of adaptation to climate change by agro-pastoralists and dryland farmers in Eastern Ethiopia, and reported

four main adaptation practices: selection of crop variety, soil and water conservation, adjusting planting dates and where possible irrigation. Significantly, distance from market, education level of household head, and access to credit affected the rate of take-up of adaptation practices. In a similar study, Yebekal, et al (2013) identified that early planting, terracing, tree planting and water harvesting and irrigation were the most commonly used adaptation strategies. Common barriers were found to be lack of seed, cash, information, oxen and shortage of land. Adaptation options for agro-pastoralists involved in cropping are therefore largely related to the extension or intensification of existing good practice (Howden, 2007). Specifically these include:

Altering inputs, such as varieties, to those with more appropriate thermal time and vernalisation requirement, and/or with increased resistance to heat shock and drought, altering fertilizer rates to maintain grain or fruit quality consistent with prevailing climate, altering amount and time of irrigation and other water management strategies.

Wider use of technologies to harvest water, conserve soil, conserve moisture (e.g. crop residue retention) use and transport water more effectively when rainfall decreases.

Managing water to prevent water logging, erosion and nutrient leaching where rainfall increases.

Improving the effectiveness of pest, insect and disease weed management practices through wide use of integrated pest and pathogen management development, and the use of varieties and species resistant to pest and disease.

In future the development and dissemination of improved germplasm may also help offset yield losses induced by climate change (Hellin et al., 2012).

## 11. Mitigation

The two greenhouse gases (GHG), methane and nitrous oxide, are the main emissions from livestock and game animals. Methane is second in importance at 15 per cent, and nitrous oxide fourth with 4 per cent of total greenhouse gas emissions.

### 11.1. National GHG emissions

Globally, the agricultural sector is not a major contributor to CO<sub>2</sub> emissions as it contributes just 4.0 per cent of total emissions. However, methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions dominate the agricultural sector and together contribute over 20 per cent of global anthropogenic greenhouse gas emissions as CO<sub>2</sub> equivalents.

By contrast, nationally Ethiopia's agricultural sector contributes the equivalent of 80 per cent of CO<sub>2</sub> equivalent emissions, mainly in the form of methane and nitrous oxide (NMSA, 2001). Methane emissions in 1994 were 1,808 Gg or an estimated 85 per cent of total national CH<sub>4</sub> emissions; and mainly the result of enteric fermentation in livestock, including from pastoral livestock. In the same year nitrous oxide emissions were 24 Gg or 81 per cent of the total national NO<sub>2</sub> emissions, mainly from fertilizer use (NMSA, 2001). As can be seen in Table 6, emissions are also increasing.

**Table 6:** Four Greenhouse Gases Emissions from the Agricultural Sector in Ethiopia (Gg)

GHG TYPE	1990	1991	1992	1993	1994	1995	% change 1990/95
Methane (CH <sub>4</sub> ): Total, all sectors	1,800	1,841	1,777	1,786	1,808	1,821	1
Agriculture	1,581	1,612	1,535	1,530	1,540	1,538	-3
Contribution of agric. (%)	87.83	87.56	86.38	85.67	85.18	84.46	
Nitrous oxide (N <sub>2</sub> O):							
Total, all sectors	11	15	15	16	24	24	119
Agriculture	7	11	11	11	19.7	20	189
Contribution of agric. (%)	63.64	73.33	73.33	68.75	82.08	83.33	
Nitrous oxides (NO <sub>x</sub> ):							
Total, all sectors	160	155	158	171	165	166	3



Agriculture	82	78	76	80	73.8	71	-13
Contribution of agric. (%)	51.25	50.32	48.10	46.78	44.73	42.77	
Carbon monoxide (CO):							
Total all sectors	7,884	7,518	7,553	7,560	7,619	7,576	-4
Agriculture	4,573	4,399	4,251	4,104	4,003	3,867	-15
Contribution of agric. (%)	58.00	58.51	56.28	54.29	52.54	51.04	

Adapted from NMSA (2001)

While it is important to recognize the role of pastoral livestock and indeed all livestock as emitters of methane, and therefore contributing to increases in global greenhouse gases, it should be noted that rangelands store an estimated 30 per cent of the world's soil carbon, in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses (White, et al., 2000; Grace, et al., 2006). What has not yet been researched in the Horn of Africa, and in smaller rangelands in particular, is the balance between gas emissions and sequestration.

## 11.2. Existing technologies/practices

Mitigation of GHG emissions in the agricultural sector can be achieved through various interventions. Some of these practices are already being trialled in Ethiopia:

- Reduction in livestock numbers
- Increasing the efficiency of livestock production through increasing feed intake, dietary manipulation, and increasing metabolic efficiency and genetic improvement in animals
- Manipulation of the rumen microbial ecosystem
- Management of methane emissions at the farm-scale.

## Rangeland improvement

Tennigkeit and Wilkes (2008) estimate that improved rangeland management has the biophysical potential to sequester 1.3-2Gt CO<sub>2</sub> equivalent worldwide by 2030, and that therefore improved rangeland management is of global importance. Significantly, FAO (2009) asserts that improved rangeland management interventions are cost effective and include: the introduction of new species and varieties that sequester carbon in the fine root zone, reducing the frequency and/or intensity of grassland fires (see Text Box

### Text Box 1: Prescribed fires

Rangelands may benefit from judicious burning to: remove un-grazed grasses and litter that might result in destructive wildfires; control the density of invasive woody shrubs and trees; reduce infestation of ticks and disease vector insects; and stimulate the growth of new grasses (IFFN, 2004). The use of prescribed fire can reduce emissions of CO<sub>2</sub> by 50 per cent of the emissions from wildfires (Fernandez and Botelho, 2003).

1), restoration of organic soils and degraded lands, extending the use of perennial crops, increasing tree cover in silvo-pastoral systems, managing grazing intensity and duration/periodicity, and improving pasture quality.

## Livestock feed improvement

Various feed interventions can improve the digestibility of ruminant feed and therefore result in reduced methane emissions. They include the following:

**Ammonization of roughage:** The treatment of crop residues with urea improves digestibility and increases intake, and reduces methane emissions per unit of animal produce (meat, milk, wool) by between 25 and 75 per cent (Sollod and Walters, 1992). The up-take of this technology is limited only by the availability and price of urea.

**Urea-molasses multi-nutrient blocks:** Urea-molasses multi-nutrient block are used as a feed supplement and also as a source of feed in drought-affected areas. Methane emissions reduction are the same as for the ammonization of roughage, at 25 per cent of emissions per unit of animal produce.

**Crop rotation:** This is a traditional farming practice in Ethiopia but in recent years it has been replaced in many areas by mono-cropping with high yielding crop varieties.

**Text Box 2: Cost estimates of treatment**

Ethiopia produces an estimated 41.5 and 30 million metric tonnes of crop residue and natural pasture dry matter equivalent, annually. The net effect of urea and molasses treatment would increase digestibility by 8 to 12 points, double the nitrogen content and increase intake by 25 to 50 per cent.

Cost of treatment:

Ingredient	Amount	Cost
Teff straw	100 kg	125
Molasses	10 kg	50
Urea	5 kg	50
Water	100 lt	5
Total		230

From a greenhouse gas emission perspective however the restoration of crop rotation offers several advantages. It also offers soil health and environmental protection benefits.

The mitigation role is the result of an increase in soil carbon through the accumulation of organic matter as different crop species have different rooting forms and depths, which helps accumulate organic matter throughout

the soil profile. West and Post (2002) found that rotation can sequester an average of  $20 \pm 12$  grms carbon/m<sup>2</sup>/yr, and that this can continue over a period of 40 to 60 years. Other long-term studies have compared continuous maize cultivation with a legume-based rotation, and found differences of up to 20mt carbon/ ha after 35 years (Gregorich et al, 2001). In addition, the soil organic matter present below the ploughed layer in the legume-based rotation appeared to be more biologically resistant; demonstrating that these deep-rooting plants are especially useful for increasing carbon storage at depth, where it is most secure and can make the largest impact on climate change mitigation. Legumes also fix atmospheric nitrogen and reduce fertilizer costs, and rotations also reduce the build-up of crop specific pests and diseases (see Table 7).



Technology/ Practice	Adaptation potential	Mitigation potential	Costs	Benefits	Environmental conditions for benefits	Unsuitable environmental conditions for benefits
Crop rotations	High	High (20mt C/ha after 35 yrs)	Variable	Increased yields - reduced agrochemical use	Higher or lower rainfall; pest/ disease prone areas; degraded soils	None

### **Development of agro-forestry and silvo-pastoral systems**

There are also adaptive response options for rangelands, including the scaling-up of agro-forestry and silvo-pastoral systems to increase tree cover. As trees are deep rooted they can access water long after grass species, and therefore can be used for dry season feeding. Common agro-forestry species include: *Leucaena leucocephala*, *L. pallida*, *Calliandra calothyrsus*, *Desmanthus virgatus*, and *Sesbania sesban*. Silvo-pastoral systems also promote the use of improved leys, fodder banks that include *Lablab*, *Vigna*, *Stylosanthes*, *Macroptilium* spp and seasonal grazing.

In some areas of Ethiopia's Rift Valley, soils are increasingly saline with the result that rangeland productivity is declining. In these areas saline tolerant species can be introduced to increase productivity, and also to help reduce salinity levels by the lowering of the water table. Some of these species are: *Acacia polycantha*; *Aeschynomene elaphroxylon*; *Atriplex halimus*; *Atriplex numularia* (salt bush); *Salix subscerata* (native salt bush). These trees and bushes can be planted in small blocks or in strips.

From a climate change perspective the benefits of increased tree density include carbon sequestration, increased livestock feed availability in the dry season, and reduced methane emissions. There are also development benefits including increased opportunities for the collection and sale of fuelwood.

## Technologies and practices for mitigation of nitrous oxide

Technologies and practices for the mitigation of nitrous oxide in relation to livestock are primarily associated with the management of manure, and there are a number of promising farm-level pilots in Ethiopia. The benefits of these pilots have been shown to be methane production for cooking (from biogas plants), which in Ethiopia results in a decrease in firewood consumption.

### 11.3 Projected mitigation of GHG emissions in 2030 through implementation of selected technologies

Projections of the impact of mitigation of anthropogenic GHGs in Ethiopia to 2030 have been calculated as equivalent to 6.70 MtCO<sub>2</sub> as the result of five key interventions (see Table 8).

**Table 8:** Projected mitigation of GHG emissions by 2030

Technology/ Practice	Objective	Item/ Case	Emission reduction (Mt CO <sub>2</sub> eq)	Assumptions & notes
Selection for meat	Meat: 5% increase by selection; by 2030 50 per cent pastoral cattle will be reached	Reduction in cattle population will be 68,1544	0.74	30% of total population is taken as pastoral; 50% of cattle herd reached by the practice; Emission factor (IPCC, 2006) 1.08
Selection for dairy	Milk incremental increased productivity	Reduction in cattle population will be 374,849	As above	As above
Supplementation + improved rangeland + improved health services	Meat	Reduction in cattle population: 1,816,576	2.5	As above

Supplementation + improved rangeland + improved health services	Milk incremental increased productivity	Reduction in cattle population: 1,816,576	0.61	As above
Improved health + early warning system	Decrease in mortality	Reduction in cattle population: 1,135,998	1.23	
Reproductive management	Milk incremental increased productivity	Reduction in cattle population: 482,799	0.52	As above
Reproductive management	Increased off-take	Reduction in cattle population: 1,448,398	1.56	As above
Reproductive management	Increase in emissions	Reduction in cattle population: 6,587,632	0.42	Increase of emission (reduced from total reductions)
Total emission reduction		Emission reduction (MtCO <sub>2</sub> eq)	6.74	

As can be seen in Table 9 the introduction of feedlots for fattening pastoral livestock will reduce greenhouse gas emissions.



**Table 9: Mitigation of GHG through the intensification meat animal production in feedlots**

Year	Amount of cattle reached with program (reduction)	No of male cattle to be taken to feedlots	No animals added to feedlot	Emission reduction (mtCO <sub>2</sub> eq)	Rate of emission increment due to fattening	Emission increment due to fattening	Assumptions
2014	33702.448	120000	120000	0.0363986	0.054	0.00648	□Total cattle population in 2013/14 (CSA) = 53,990,061
2015	56170.747	200000	80000	0.06066441	0.054	0.0108	
2016	84256.121	300000	100000	0.09099661	0.054	0.0162	
2017	152212.052	541962	241962	0.16438902	0.054	0.029265948	□Population of lowland cattle is 30% of the national Percentage of Lowland cattle (0.3*53990061)= 16,197,018
2018	220167.984	783924	241962	0.237781423	0.054	0.042331896	
2019	288123.916	1025886	241962	0.31117383	0.054	0.055397844	
2020	356079.847	1267848	241962	0.38456624	0.054	0.068463792	
2021	424035.779	1509810	241962	0.457958641	0.054	0.08152974	
2022	491991.711	1751772	241962	0.531351047	0.054	0.094595688	□Population of male cattle (44.5%) is 7,207,673
2023	559947.642	1993734	241962	0.604743454	0.054	0.10766164	
2024	627903.574	2235696	241962	0.67813586	0.054	0.120727584	□Productivity in meat =25%; Off-take = 3 months
2025	695859.506	2477658	241962	0.751528266	0.054	0.133793532	
2026	763815.437	2719620	241962	0.824920672	0.054	0.14685948	□33% of male of current yr goes to feedlot
2027	831771.369	2961582	241962	0.898313078	0.054	0.159925428	
2028	899727.300	3203544	241962	0.971705484	0.054	0.172991376	
2029	967683.232	3445506	241962	1.045097891	0.054	0.186057324	□Productivity of meat increases by 25% Lifespan of cattle in pastorals is 10 yrs
2030	1035637.512	3687462.2	241956.1	1.118488513	0.054	0.199122954	
	Emission reduction by 2030 (mtCO <sub>2</sub> eq)			1.1184885			□25% reduction in marketing age due to good handling in feedlots
	Corrected net emission (mtCO <sub>2</sub> eq)			0.9193655			
							Corrected for emission increment due to fattening

## 12 Conclusions and Recommendations

Pastoralism is widely practiced throughout the world, and it is estimated to be the primary livelihood for possibly half a billion pastoralists and agro-pastoralists. Pastoral systems dominate the world's arid and semi-arid rangelands, including in the Horn of Africa. Eastern Africa is estimated to be home to 50 million pastoralists and agro-pastoralists.

As one of the most economically, culturally and socially sustainable strategies for Ethiopia's arid and semi-arid rangelands, investing in pastoralism can help secure livelihoods, conserve ecosystem services, promote wildlife conservation and strengthen cultural values and traditions (ILRI 2006).

As a livelihood system, pastoralism is less well understood than sedentary farming, for this reason it is also recommended that increased attention be given to support pastoral research—including poverty analysis, food security, population and livelihood trend analysis, climate change trends and forecasts, climate change adaptation/mitigation opportunities and threats, and the impact of development assistance and investment. Research is also required in the regions—particularly Afar, Somali, Borana (southern Oromia) and South Omo (SNNP Region)—in order to better understand the heterogeneity of Ethiopia's rangelands, and to better plan investment and development that will factor in local weather events, diseases, rangeland management challenges and conflicts.

For agro-pastoralists, the forecast of impact of climate change includes new challenges in seasonal cropping as temperatures (of up to 2.6°C) and evapotranspiration will increase, rainfall will become more variable and at times much more intense, and therefore the seasonal availability for soil moisture will fluctuate. These fluctuations are expected to result in changes in crop yields. Cropping may in some places be rendered impossible, in particular if drought cycles are shortened. In order to adapt, agro-pastoralists will need to identify more drought tolerant crops and varieties, such as replacing maize with sorghum and millet.

Rises in temperature and changes in rainfall will also impact on rangeland productivity and may result in a loss of more palatable grasses, particularly if herd management is not improved and the recovery period for these species

between grazing events continues to decrease. If this is the case, livestock production and productivity can be expected to be affected, and this further impacts on household food security of pastoral and agro-pastoral households.

Recognising the value of grasslands as carbon sinks, and increasing investment in the rangelands (through both pasture regeneration and management, and the introduction and expansion of agro-forestry and silvo-pastoral systems) will not only increase carbon sequestration but also result in improved livestock productivity. It is therefore recommended that Ethiopia gives increased attention to carbon sequestration through improved rangeland management practices including: better range vegetation management, adjusting stocking rate with grazing capacity, use of prescribed fire, improved supply of water, employing silvo-pastoral systems, production intensification through feedlots, and improving marketing and offtake rate. In addition, it will be important to invest in alternative livelihoods that offer new and vibrant livelihoods for the growing number of people that are in transition out of pastoralism.

The report identifies a number of promising climate change adaption and mitigation measures. Piloting of some of these measures has apparently generated promising results implicating possible scaling out in the future. For pastoral communities key interventions possibilities are outlined as follows:

- *Livestock management systems*: water and shade development; improvements in herd composition; destocking in times of drought.
- *Production adjustment*: diversification of livestock species; intensification and/or better integration of livestock and crop production; changing land use and developing and introducing irrigation where found economically viable; altering the timing of operations; and conservation of ecosystems;
- *Breeding strategy*: identifying and strengthening local breeds that have adapted to local climate stress and feed sources; where possible improving the local genetic make-up of animals through cross-breeding with heat and disease tolerant breeds.
- *Market responses*: improved trade and credit schemes.
- *Institutional and policy change*: the introduction of insurance and subsidy schemes



Specific to agro-pastoralism, the most promising pilots are suggested as follows:

- *Crop types*: changing crop types and varieties to those that are more drought-tolerant.
- *Water management*: changing planting dates and use of inputs, rapid scale-up of rainwater harvesting, soil and water conservation and irrigation.
- *IPM*: improved insect, disease and weed management through integrated pest and pathogen management development.
- *Forecasting*: improved use of climate and weather forecasting to inform decision-making.
- *Livelihood diversification*: further and accelerated income and livelihood diversification.

In order to drive positive change and scale-up good practice, FAO's Grassland Working Group (2009) recommends that relevant government institutions at national and local level are strengthened and supported to create and maintain an enabling policy framework that will result in better managed rangelands and an increase in the carbon sequestration capacity. Suggested areas for capacity building include:

- full GHG accounting
- measurements and monitoring
- skills transfer
- dryland policy development
- finance options.

At national level, necessary undertakings have been suggested: solve the underlying constraint of the insecurity of land tenure; mainstream mitigation in agricultural policies; improve adoption of win-win management practices that will result in sustainable production intensification and climate change mitigation. These could be promoted through Farmers Field Schools' adult education schemes and through pastoral associations and/or pastoral field schools.

Finally, while there is a growing fund of information and generic research findings on Ethiopia's rangelands and its people, climate change research is still in its formative stage and more detailed research is required, in particular

research that is specific to Ethiopia's diverse rangeland types. It is important that Ethiopia is able to research and document greenhouse gas emissions and carbon sequestration in different rangeland types. In addition, Ethiopia will need to expand its capacity to analyse and interpret global and regional climate change models, and weather forecasts, and associated implications for different pastoral and agro-pastoral communities including for both men and women. Ethiopia will also need to develop a climate mitigation and verification capacity in order to have the potential to benefit from global carbon markets, if and when they recover.



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