

ETHIOPIAN PANEL ON CLIMATE CHANGE

FIRST ASSESSMENT REPORT

SUMMARY OF REPORTS FOR POLICYMAKERS



Ethiopian Panel on Climate Change

First Assessment Report

Summary of Reports for Policymakers

Ethiopian Academy of Sciences



SCIP

Ethiopian Academy of Sciences House No. 199, Woreda 9, Gulele Sub-city Near Commercial Bank of Ethiopia, Gulele Branch P. O. Box: 32228 Addis, Ababa, Ethiopia

Tel: +251 112 59 57 45/50 or +251 112 59 09 43

E-mail: essecretariat@gmail.com or eas@eas-et.org/
epcc-officer@eas-et.org

Website: www.eas-et.org/ www.epcc-et.org

Financed by the SCIP Fund: The SCIP Fund is financed by DFID UK, Aid, The Royal Norwegian Embassy and The Royal Danish Embassy

© 2015 Ethiopian Academy of Sciences. All rights reserved

Printed in Addis Ababa, Ethiopia

Citation- This document may be cited as follows:

Ethiopian Panel on Climate Change (2015), First Assessment Report, Summary of Reports for Policy Makers, Published by the Ethiopian Academy of Sciences

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.

Acknowledgements

This book is part of the First Assessment Report of the Ethiopian Panel on Climate Change (EPCC). The EPCC, established under the auspices of the Ethiopian Academy of Sciences (EAS), primarily to, inter alia, produce periodic assessments of climate change issues in Ethiopia, is a sub-project of the “Environment Service and Climate Change Analyses Program (ESACCCAP)” project jointly run by the Ethiopian Academy of Sciences, the Climate Science Centre (CSC) and the Horn of Africa Regional Environment Centre and Network (HoA-REC&N) of Addis Ababa University. The Ethiopian Academy of Sciences gratefully acknowledges the Department for International Development (DFID) UK, the Danish Government and the Norwegian Government for their support to the Project through the Strategic Climate Institutions Programme (SCIP).

The book was produced through exemplary collaboration and contribution of Dr. Gizaw Mengistu, Dr. Seme Debela, Agricultural Knowledge Learning Document Policy (AKLDP)/ Resilience Learning Programme (RLP), Dr. Menassie Gashaw, Prof. Woldeamlak Bewket, Dr. -Ing. Ababayehu Assefa, Dr. Daddi Jima and Dr. Tassisa Kaba. EAS gratefully acknowledges them for their dedicated service. The First Assessment Report has also benefited from the validation workshop conducted on 20 and 21 November 2014. The Academy gratefully acknowledges the participants for their input.

Masresha Fetene (Prof.)
Executive Director, Ethiopian Academy of Sciences

Table of Contents

Physical Science Basis	1
Agriculture and Food Security	11
Mixed Crop Livestock System	11
Pastoral and Agro-Pastoral System	25
Biodiversity and Ecosystem	31
Water and Energy	43
Water	43
Energy	53
Health and Settlement	63
Industry Transport and Infrastructure	77

Physical Science Basis

A. Introduction

This Summary for Policy makers follows the structure of Working Group I Report. Working Group I is established by the Ethiopian Panel on Climate Change under the Ethiopian Academy of Sciences to compile and assess the physical science aspect of climate change unique to Ethiopia in a consistent manner with the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). As the Summary for Policy makers is based mainly on Working Group I report, it shares the merit and limitations of that Report, which are highlighted in the preface of the Report.

The narrative in this Summary for Policy makers is supported by number of conclusions, of which the ones highlighted by yellow background color are particularly uniquely valid for Ethiopia. These conclusions, taken together, provide a concise Summary on the state of current and future climate over Ethiopia. The basis for substantive paragraphs in this Summary for Policy makers can be found in the chapter sections of the underlying Report. The references are given in curly brackets.

B. Observed changes in the climate system

Observations of the climate system are based on direct measurements and remote sensing from satellites and other platforms globally. On a local scale, a number of case studies, based on a large number of short and long-term in-situ observations and modeling provide information on changes in the climate system and its impact at the local scale. Paleoclimate reconstructions, such as tree ring, and isotope fractionation extend some records back hundreds to millions of years both at the local and global scale. Together, these observations avail a sufficient and detailed view of the variability and trends in the atmosphere, the ocean, the cryosphere, and the land surface.

Warming of the climate system is unequivocal, and many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, sea level has risen, and some water bodies, such as lakes, have dried up, the concentrations of greenhouse gases have increased. {1.0, 1.1, 2.2-2.6, 3.1, 3.2, 4.1-4.4, 5.1-5.4}

B.1 Atmosphere

The observed increasing changes in warm extremes are consistent with the already happening global warming. The mean seasonal rainfall is also affected in response to climate change. Over Ethiopia, these changes have been observed in the following contexts:

- The significant, steep decreasing summer rainfall trends (exceeding 25 mm.decade⁻¹) over southwestern and western Ethiopia and increasing trend (exceeding 24 mm.decade⁻¹) over northern and northeastern regions as well as isolated places across central Rift Valley of the country are observed during the 1978-2007 (see Fig. 1, left panel).
- Summer rainfall over central Rift Valley areas and the nearby highlands have decreased whereas rainfall over southern Rift Valley areas has increased (see Fig. 1, left panel).
- The substantial decreasing trend of up to 28 mm.decade⁻¹ has been observed over southern and adjoining eastern highlands in spring rainfall during the last three decades (see Fig. 1, right panel).

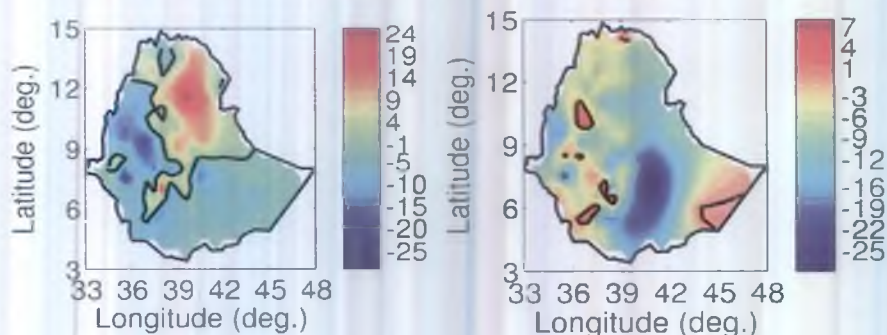


Figure 1. The linear seasonal rainfall trend (mm/decade) over 1978-2007 period for summer (left) and spring (right) based on gridded rain gauge observations (Source: Unpublished work by this author).

- The seasonal mean temperatures exhibit warming trends of up to 0.8°C/decade over northern half of Ethiopia (high confidence) except during summer season where warming is limited to north of Lake Tana and northeastern Ethiopia (see Fig. 2).

- The southeastern part of the country has also experienced warming trend of about 0.4°C/decade in winter and summer (high confidence). Except for this departure, the southern half of Ethiopia has experienced normal-to-cooling trend with the cooling trend confined mainly to southwestern Ethiopia (see Fig. 2).
- Climate change also affects the distribution of temperature. For example, the 90th percentile minimum temperature exhibits increasing trend over western, northern and eastern Ethiopia in spring, summer and autumn seasons whereas central Ethiopia and southwestern Ethiopia exhibit normal to decreasing trend. {3.2}

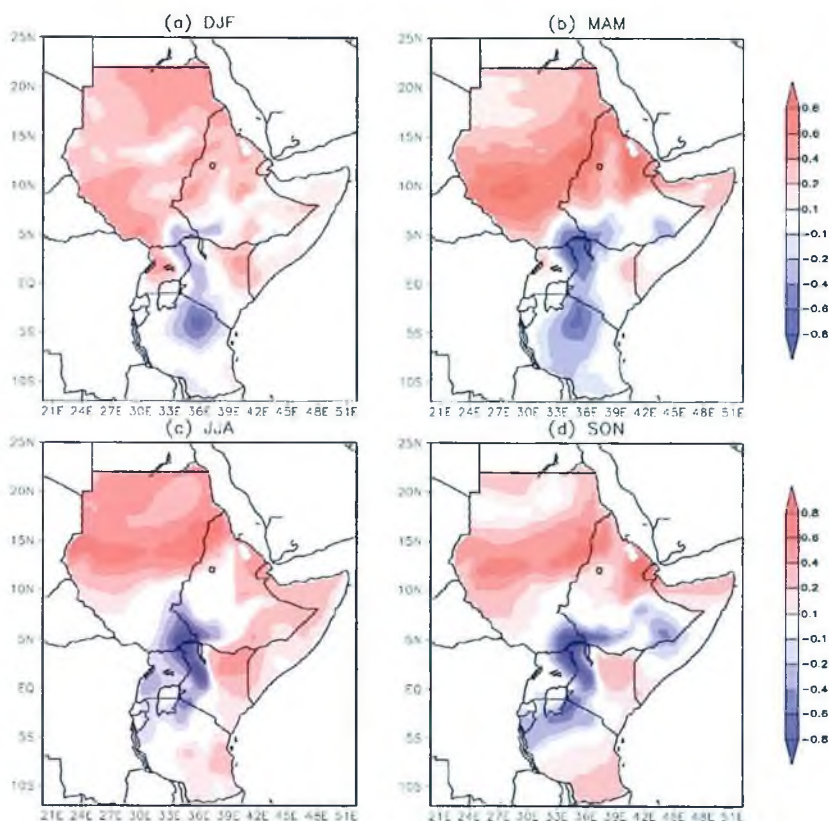


Figure 2. The linear seasonal mean temperature trend (°C/decade) over 1981-2014 period for (a) winter (DJF); (b) spring (MAM); (c) summer (JJA) and (d) autumn (SON) based ERA-Interim temperature data (Source: Unpublished work by this author).

B.2 Ocean

According to the Fifth IPCC Assessment Report, the observed trends over the Indian Ocean include a decrease of sea level pressure and an increase of sea surface temperature over the tropical Indian Ocean. The Indian Ocean Basin Mode (IOBM) has been shown to have exhibited a strong warming trend (significant at 1% since the middle of the 20th century). The implication of these changes for the region and Ethiopia are:

- Impacts on the rainfall pattern, as the SST anomalies in the Indian and Pacific Oceans have already been established to have a fundamental influence on Sahel rainfall and the Nile flows from historical records.
- The changes in the Walker circulation due to extension of Warm Pool westward into the Indian Ocean which affects convection and precipitation patterns, the easterly trade winds, oceanic upwelling and ocean biological productivity.{2.6}
- As evaporation, convection, and precipitation have increased over the Indian Ocean as a result of the shift in the walker circulation, circulation has been altered in surrounding areas, including Ethiopia.

B.3 Cryosphere and Sea Level

Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent. The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901 to 2010, global mean sea level rose by 0.19 (see IPCC AR5 report). The changes are global in nature and affect the climate system as a whole with no unique and local implications. Therefore, Ethiopia is affected by the changes as part of the global system.

B.4 Carbon and Other Biogeochemical Cycles

The atmospheric concentrations of major greenhouse gases (GHGs), such as carbon dioxide, methane, and nitrous oxide, have increased to levels unprecedented in at least the last 800,000 years. The 1750 globally averaged

abundance of atmospheric CO₂ based on measurements of air extracted from ice cores was 278 ± 2 ppm. The current level of CO₂ is 400 ppm, which is 1.4 times the amount recorded in the pre-industrial time.

- Global estimates indicate that deforestation can account for 5 billion metric tons of CO₂ emissions, or about 16% of emissions from fossil fuel sources. Tropical deforestation in Africa, Asia, and South America are thought to be the largest contributors to emissions from land use change globally (see IPCC AR5 report).
- In Ethiopia, there were increasing trends of greenhouse gas emissions in the country in the period from 1990 to 1995. The relative comparisons of increase indicated that, CO₂ have increased by 24% while emission of CH₄ and N₂O increased by 1% and 119%, respectively. Aggregate greenhouse gases emissions in terms of CO₂ equivalents have increased by 12%. {2.3}

C. Drivers of Climate Change

Both the Fifth Assessment and the Fourth Assessment Reports of the IPCC indicate that increasing atmospheric burdens of well-mixed GHGs resulted in a 9% increase in radiative forcing (RF) from 1998 to 2005 and in a 7.5% increase in RF from 2005 to 2011, with carbon dioxide (CO₂), contributing 80% of these amounts.

Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions.

Available studies on land use and land cover change, focused mostly on the highlands than the lowlands of Ethiopia, have indicated substantial land degradation and deforestation since 1950s which add up to the global carbon dioxide concentrations. {2.3}

D. Understanding the Climate System and its Recent Changes

One of the most challenging and uncertain aspects of present-day climate research is associated with the prediction of a regional response to a

global forcing. Evaluations of the GCMs show that they still have significant systematic errors over Africa. These are exacerbated over Ethiopia due to interactions of large-scale climate system with its complex topography.

D.1 Evaluation of Climate Models

Climate models have improved since the AR4. Models reproduce observed continental-scale surface temperature patterns and trends over many decades; including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (See IPCC AR5 Report).

- The long-term climate model simulations show a trend in global-mean surface temperature from 1951 to 2012 that agrees with the observed trend (very high confidence). (See IPCC AR5 Report).
- On regional scales, the confidence in model capability to simulate surface temperature is less than for the larger scales. However, there is high confidence that regional-scale surface temperature is better simulated than at the time of the AR4 (See IPCC AR5 Report).
- There has been substantial progress in the assessment of extreme weather and climate events since AR4. Simulated global-mean trends in the frequency of extreme warm and cold days and nights over the second half of the 20th century are generally consistent with observations (See IPCC AR5 Report).
- Some important climate phenomena are now better reproduced by models. There is high confidence that the statistics of monsoon and El Niño-Southern Oscillation (ENSO) based on multi-model simulations have improved since AR4 (See IPCC AR5 Report).
- At smaller scale, as in the case of Ethiopia, climate model can capture the structure of the dominant atmospheric circulation patterns. The regional climate model (RCM) simulations capture the low level jet (LLJ); Tropical Easterly Jet (TEJ); and the African Easterly Jet (AEJ). {6.4.3}
- The RCM reproduces the spatial pattern of the mean temperature

climatology of all seasons with moderate warm and cold biases in terms of absolute magnitude over low and highlands of Ethiopia, respectively. The RCM reproduces the major features of precipitation in all seasons. {6.4.3}

E. Future Global and Local Climate Change

The hierarchy of climate models are used to simulate changes based on a set of scenarios of anthropogenic forcings.

E.1 Temperature

Warming will continue to exhibit interannual-to-decadal variability and will not be regionally uniform (see IPCC AR5 report).

It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase (see IPCC AR5 report).

- For Ethiopia, the range of annual temperature increase for all the RCPs by 2100 relative to the 1975–2005 baseline mean ranges from -0.5°C to 6°C .
- Under RCP2.6, the mean temperature increases by approximately 1°C at the end of the century relative to the baseline, and by 5°C under RCP8.5. For RCP 4.5, which represents the moderate scenario, the projected increase in temperature is around 2°C . {7.4}
- There will be spatial variation on the magnitude of the change in mean temperature. An increase of mean surface temperatures for the end-term relative to 1975–2005 is likely in the range of 0.8°C to 1.1°C (RCP2.6), 1.8°C to 2.6°C (RCP4.5), 2.6°C to 3.6°C (RCP8.5). {7.4}

E.2 Rainfall

Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions. Changes in the near-term and at the regional scale will be strongly influenced by natural internal variability and may be affected by anthropogenic aerosol emissions (see IPCC AR5 report).

In line with this, the following are captured by the ensemble mean of simulations of the fourteen models for the future over Ethiopia:

- An increase in precipitation is expected during the 21st century, except for the projections under RCP2.6 over the eastern part of the country which shows prevalence of normal to decreased precipitation from place to place in this part of the country. The ensemble-mean annual precipitation for all RCPs increase by 4% to 12% by 2100 compared to the 1975– 2005 mean.{7.3}
- The response of different parts of the country to the various RF of the RCPs is slightly non-uniform. The percentage increase in rainfall is high over northern part of Ethiopia under RCP2.6 scenario, and over southern and southeastern part of the country under RCP4.5 and RCP8.5 scenarios.{7.3}



1. Introduction: Attributes of Ethiopian Agriculture

Ethiopia's agricultural production system falls into two broad categories:-1) mixed crop-livestock production system in high and mid-altitude areas and 2) pastoral/agro-pastoral production system in low altitude dry land areas. Crop and animal productivity in both broad production systems is low due to inadequate availability as well as poor adoption of productivity, enhancing technologies, inappropriate land management practices that lead to serious land degradation and soil fertility depletion. The impact of these constraining factors is severely exacerbated by major climate extremes such as droughts and floods whose occurrence is increasing at an alarming rate over the past five or so decades. Socio-cultural and economic factors, such as rapid increase in population and urbanization, rapidly increasing unemployment and poverty have also exacerbated the food insecurity situation of the country.

In general, the occurrence of climate change and its impact on Ethiopian agriculture is generally 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 adequate empirical and site-specific data and information. Despite that, however, whatever is available from various sources is compiled in the First Assessment Report on climate change in Ethiopia, a summary of which is presented in this Policy Brief. This Policy Brief particularly focuses on Agriculture and Food Security in Mixed Crop Livestock Systems as has been affected in the past as well as in the present or will be impacted upon in the coming decades by climate change and variability. It will deal with 1) key findings gleaned from all available sources and 2) future trends and policy recommendations for actions.

2. Key Findings

2.1. Impacts of climate change/variation

Climate change in the form of droughts, floods and hail storms has been causing serious damage to life, property and natural resources thus, affecting lives and livelihoods and the economy of the country. For example, floods that occurred in 2006 across the country claimed 719 lives, displaced over 241,699 people, severely damaged infrastructures and houses, and caused property loss worth millions of USD. The impacts of these severe climatic events manifest themselves through the following:

2.1.1 Impacts on crop production

Crop production is impacted upon in various ways. One of the important factors that affect crop production and productivity is associated with atmospheric CO₂ concentration which is responsible for temperature increase due to what is known as the “Green House” effect. This has both a positive and negative effect, depending upon its concentration level in the atmosphere. Although there are no detailed studies on these factors under Ethiopian condition, crop simulation models under various climate change scenarios seem to indicate the following:

- Length of the growing period (LGP) for crops may be reduced due to high temperature and uncertain rainfall conditions which are reflected by low yields due to inadequate period of time for metabolic processes that determine plant growth and development.
- Areas suitable for production of the country’s major food crops could be shifted towards less suitable areas.
- Crop productivity will be negatively affected both by high temperatures and reduced precipitation.
- Development and dynamics of crop diseases and pests will increase crop losses as adaptation zones of weeds and pests will expand due to geographic shifts through changes in seasonal extremes.

2.1.2. Impact on livestock production

The impact of climate change on livestock production occurs through the following three events, which could have direct and indirect effects:-

- Herd dynamics will shift drastically downward under rainfall deficit conditions.
- Animal feed and forage will be negatively affected not only in quantity but also in quality as species composition and performance change. It is known from global data base that changes in temperature and moisture regimes negatively affect the growth, habit/competition dynamics and range of adaptation of forage species.
- Impact on livestock diseases: will be more severe under increased temperatures and inadequate rainfall regimes. Increase in temperature and rainfall may lead to increased spread of existing vector-borne diseases and macro-parasites, accompanied by the emergence and circulation of new diseases.

2.1.3. Impact on water resources

Climate change, through increasing temperatures and rainfall variability, will affect both the supply and demand of water for agricultural activities. In some areas of the country, annual rainfall is predicted to decrease while increases are expected in others. Higher temperatures will also 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 in the northern highlands of Ethiopia revealed that the actual evapo-transpiration (AET) will increase by 7-16.1% by 2045-2065 and this will increase to 8.1- 16.9% by 2080-2100, negatively affecting soil water balance, ground water level and subsequently stream flow.

2.1.4. Impact on the national economy

Ethiopia's economy as well as a large proportion of its population is heavily dependent on the performance of the agricultural sector which is regularly affected by annual rainfall received. Therefore, climate change very much affects revenue generated through agriculture both at household and national levels. Some studies in Ethiopia indicate that both increasing temperature and

decreasing rainfall will reduce net revenue from crop and animal production. Based on such studies, it can be concluded that the country's GDP is heavily dependent on agriculture and it is highly correlated with rainfall. Another interesting study indicated that revenue from crop production fell with increased temperature and rainfall because the positive effect of increased rainfall was offset by increased temperature.

2.1.5. Impact on food security

A significant proportion of people in the crop dependent highlands as well as in lowland pastoral/agro-pastoral areas 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 maize as a case study, indicates that the number of food insecure people in Ethiopia will 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.

2.2. Vulnerability of Ethiopian Agriculture to Climate Change

The International Panel on Climate Change (IPCC) defines vulnerability "as the degree to which a system is susceptible or unable to cope with adverse effects of directional climate change, variability and extremes." The vulnerability of an agricultural production system in a given country/region/locality is determined by the interaction of three major components, i.e. "exposure," "sensitivity" and "adaptive capacity."

2.2.1. Key drivers of vulnerability to climate change in Ethiopia

Climatic conditions in Ethiopia are determined by phenomena that encompass global, regional and local conditions. The global determinants are associated with *El Niño* and *la Niña* events both of which are related to shifts of warm tropical pacific air currents occurring in the Pacific Ocean. These events lead to extreme weather events such as droughts and floods. The other component of climatic drivers arises from regional events that result in the movement of equatorial low pressure zones across the country. Non-climatic conditions that result in vulnerability of Ethiopian agriculture

relate to 1) agricultural land use/land degradation 2) population dynamics (demography), 3) technology and 4) socio-economic factors.

2.2.2. Components of vulnerability

Vulnerability of Ethiopian agriculture can be described in terms of exposure to climatic factors; sensitivity to the impacts of climate factors; and adaptive capacity to withstand the impacts. Results from limited case studies on these factors in Ethiopia are summarized below.

- Case studies on exposure in selected parts of the country clearly show that exposure is a common phenomenon associated with increased temperatures and decreasing rainfall across locations although there is variability in the degree to which such exposure is manifested.
- Case studies on sensitivity also show that different localities have differing levels of sensitivity to climate change/variability. The major factors influencing sensitivity relate to bio-physical characteristics of the areas, population dynamics, and levels of poverty in the population as well as other socio-economic and technological endowments. Thus, localities with degraded environments, greater number of poor people, poorly developed agricultural technologies and infrastructure are more sensitive to the effects of climate change/variability.
- Case studies on adaptive capacity show that localities that have better environmental, technological and socio-cultural conditions are shown to better adapt to difficult climate change/variability conditions.

2.2.3 Integrated analysis of vulnerability of agriculture

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; at 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. Based on the findings of these case studies, indications are that some regions of the country are variably vulnerable to

the effects of climate change. Integrated analysis of exposure, sensitivity and adaptive capacity across regions seems to indicate that the Southern Nation, Nationalities and People, and Benshangul-Gumuz Regional States are less vulnerable than Afar, Amhara, Oromia and Tigray.

2.3. Adaptation to Climate Change/Variability

2.3.1. Adaptation practices in Ethiopia

Adaptation practices to climate change/variability can be looked at from two broad levels:-macro level and micro level. In Ethiopia, adaptation practices have been going on for many years now. At the macro level, government initiated and donor supported programs include early warning and response mechanisms, safety net programs, natural resource management and rainfall-index-weather insurance schemes, particularly in crop production activities. At the micro level, adaptation practices implemented by farmers and/or community includes initiatives such as forestation/afforestation, area enclosures, changes in crops and cropping systems, water harvesting, and alternative income sources.

2.3.2. Barriers to adaptation practices

Local level studies in some parts of Ethiopia indicate that the major barriers to adaption, reported by small-scale farmers/herders, include shortage of land and labor in addition to lack of finance, climate information, irrigation potentials and improved technologies. The issues of finance impinge mostly on the ability of farmers to purchase yield enhancing inputs. There are government efforts to improve the technical knowledge of farmers through agricultural extension programs.

2.3.3. Household determinants to adaptation practices

Studies, conducted in some localities of Ethiopia, seem to indicate that a number of factors act as determinants to adaptation practices. The most prominent of these are associated with sex, household size, livestock ownership, education level, social capital, access to credit, and information on climate and extension services. Based on these findings, the studies conclude that those families that have the advantage of larger family size, land and other economic resources and education opportunities have

greater propensity to adapt to climate change than otherwise. The studies also emphasize the need for gender equality in enabling female-headed households to access resources and extension services in par with male-headed households.

2.4. Adaptation options

Very little actual research has been conducted to determine the best adaptation options to pursue under Ethiopian conditions. Despite such limitations, the following adaptation options are considered. It should, however, be noted that as each of these options are quite involved and detailed and only the salient points related to each option is mentioned here.

2.4.1. Agro-ecosystem based

This is an agro-ecosystem-based adaptation framework tested at the community level in Ethiopia. The framework focuses on community activities through capacity-building, environment management, improved agricultural production systems and enhances value chains in order to adapt to climate change. 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 level 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. Implementation is facilitated through innovation platforms that encourage community participation.

2.4.2. No or low-regret options

A large number of no/low-regret adaptation options, that can reduce agriculture's vulnerability to climate change, are proposed by several research and/or development organizations. These adaptation options were compiled and detailed mainly by the National Adaptation Program of Action, the Ethiopian Program of Adaptation to Climate Change and Agriculture Sector Program of Plan on Adaptation to Climate Change. These adaptation options rely on applying "best practices" that have been developed through agricultural research and/or local experience and have been in use by Ethiopian

farmers/herders over a long period of time. Additional areas of focus include climate monitoring and forecasting, disaster risk management, food security, integrated pest and disease management, etc. Application of these options not only help to meet current climate change/variation constraints but also help in managing future changes/variations by introducing adjustment factors developed through R & D in agriculture.

2.4.3. Options based on climate change scenarios

There is very little research output on adaptation options developed based on climate change scenarios of Ethiopia. The most important line of research in this regard is The World Bank's research that proposed adaptation options based on four scenarios of climate change (Wet1, 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.

2.4.4. Adaptation in the crop and livestock production sectors

In the crop production sector, areas that need to be focused more for improved adaptation to climate change/variation include changing crop types and varieties, the use of fertilizers (organic, if possible), improved farm management practices, better control of pests and diseases through Integrated Pest Management (IPM) and increased use of irrigation. Areas of focus in the livestock production sector include improvement in local breeds through appropriate breeding and selection, introducing better feeds and feeding systems, improvement in the livestock management system and the diversification of animal types (switch from cattle to small ruminants).

2.5. Climate change mitigation

As indicated earlier, one of the factors contributing to climate change/variation is associated with greenhouse gas (GHG) emissions such as Carbon Dioxide, Methane and Nitrous Oxide. Such emissions could come from natural and man-made sources. Ethiopia's contribution to the global emission of GHGs is very insignificant, representing no more than 0.3 %. However, the rate of emission could escalate if appropriate measures are not put in place at the outset. A brief summary of findings along this line is discussed as follows.

2.5.1. Sources GHG emissions:

In the Ethiopian context, the sources of GHGs emanate from the agriculture, industry, transport and construction sectors. However, the greater portion of GHG emissions is contributed by agriculture, representing about 50 %, while forestry contributes an additional 37 %. The major sources of GHG emissions in agriculture and related activities can be described as follows.

Crop production:-The main sources of GHG emissions related to crop production include conversion of forest and grazing land into cultivation, the use of agricultural chemicals such as fertilizers and the application of inappropriate farm management practices related to land preparation that expose land to the release of CO₂ and other GHGs. Because of the food security needs of the country, crop production is set to increase through bringing more land under cultivation, thus creating more avenues for GHG emissions.

Livestock production:-The causes of GHG emission from livestock production are related to the formation and release of CH₄ from enteric fermentation and the release of both CH₄ and N₂O from inappropriate manure management practices. Among the livestock species contributing more GHGs are cattle whose number is set to increase in the long-term. The impact of livestock on GHG emissions are caused by two major factors, i.e., projected increase of the livestock population over time and the over-dominance of indigenous breeds in the national herd. Another important point along this line is the use of grass and forage species whose digestibility is poor.

Natural resources management:-The mismanagement of natural resources has gross consequences not only for the loss of precious resources but also for significantly contributing to climate change through GHG emissions. The major areas of concern in this respect include soil erosion and land degradation, deforestation, land conversion, desertification, grass land and forest fires.

2.6. Mitigation of GHGs from agriculture

Mitigation practices required to minimize GHG emissions from crop and animal production will be exactly the opposite of the actions that lead to

enhanced production and release of GHGs in the first place. These will be summarized as briefly as possible in the following paragraphs.

2.6.1. Mitigating GHG emission from crop production

Emissions from crop production 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 synthetic fertilizers. The introduction of lower-emitting techniques for agriculture offers an opportunity to check this increase while maintaining production levels. This initiative includes, among other things, improved agronomic practices that increase soil carbon storage, nutrient management, leading to more efficient use of carbon/nitrogen, improved tillage and soil management practices, introduction of integrated mixed crop-livestock-agro-forest production systems, soil and water management system such as terracing, and water-harvesting techniques, etc.

2.6.2. Mitigating GHG emission from livestock production

GHG emissions from livestock production is associated with the huge national herd size, the over-dominance of relatively inefficient indigenous animal population as well as the application of inefficient feed and feeding systems. As a result, the production and productivity of small holders is much lower than the potential. These deficiencies in production and productivity can be improved 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, complemented by reduced livestock population, inevitably leads to culling unproductive animals and reduced headcount gives chance to farmers to shift to better management of fewer productive animals. As this shift enhances market-oriented production system such as the operation of feedlots, it automatically leads to increased off-take rate at early age which means quality live animal and meat for both export and domestic markets. Increasing off-take rate is the major strategy in decreasing GHG emission per animal and decreased number of animals. It should, of course, be noted that reducing the national herd size could negatively impact on crop production activities that very much depends on animal traction

power. However, this can be compensated for by introducing mechanized agriculture where feasible.

3. Future trends and policy directions

3.1 Future trends

The main findings of the First Assessment Report on Climate Change in Ethiopia, in relation to the effects of climate change on Ethiopian agriculture, concludes:-1) climate change has been happening and will continue to happen with severe impacts on crop and animal production as well as on food security and the national economy, among others, 2) Ethiopian agriculture will continue to be vulnerable to the vagaries of weather, 3) both traditional and science-based adaptation measures developed and applied in the past will not be adequate to meet impending challenges, and 4) mitigation measures will need to be strengthened through appropriate actions.

3.2 Policy directions

Based on such predicted trends, it is necessary to establish ways and means to minimize the negative impacts of climate change through appropriate policy formulation and implementation. However, this is not to say that there have not been policy directions and strategic actions aimed at counteracting the expected negative impacts on agriculture and food security in Ethiopia. The Government has already put in place wide-ranging policies and strategies aimed at addressing climate change issues through consultations with and studies by relevant organizations. Thus, future policy direction is largely a matter of strengthening these efforts through adequate political and financial support as well as strengthening implementation capacity. The Government's awareness of the problem and the actions that need to be taken are formulated in its Climate Resilient and Green Economy (CRGE) strategy documents, I and II, It should also be noted that there are a number of other supportive actions under implementation through other programs/projects such as productive safety-net and associated programs, early warning system, index insurance, strengthening the national capacity for agricultural research and extension systems, development of community assets such as irrigation and infrastructure, to mention just a few.

Agriculture and Food Security

Pastoral and Agro-Pastoral System

1. Introduction

Pastoralism is an economic activity and way of life practiced throughout the world, and is estimated to be the primary livelihood for up to half a billion people. The rangelands of sub-Saharan Africa, the intensely cold grasslands of central and northern Asia and northern Europe, and the world's high mountain grasslands are all occupied by pastoralist and agro-pastoralist communities. 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.

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 living mainly in Afar, Beni Shangul Gumuz, Gambella, Oromiya, and Somali Regions. Pastoralists are found in 124 districts or *woredas*, in 21 zones and seven regions, where they inhabit arid and semi-arid rangelands which account for 65 per cent of the national landmass of Ethiopia. These rangelands are typically below 1,500m in altitude, with average annual rainfall of between 100 to 700mm.

Livestock production in pastoralist areas of Ethiopia is an increasingly important component of the national economy. Between 2005 and 2013, the number of live animals exported formally from Ethiopia increased from 163,000 to 680,000, and the amount of meat exported increased from 7,717 tonnes to 16,500 tonnes. Most of these animals were sourced from pastoralist areas of the country. However, sustaining or increasing these benefits will require further support to pastoralist production systems. This policy briefs outlines key areas where support is needed.

2. Challenges in Ethiopia's dry lands

The impressive performance of pastoralist systems in contributing to livestock and meat exports has occurred in the face of various challenges to the basic production system.

Strategic mobility – central to the viability and efficiency of livestock production in Ethiopia's pastoral and agro-pastoral areas is a capacity to move herds to access rangeland and water. The African Union uses the term

“strategic mobility” as a way of recognizing that these movements are not random, but logical responses to maximize productivity in areas with highly variable rainfall. However, mobility is increasingly compromised due to factors such as competition with agricultural land, local conflicts and private enclosure of rangeland. Furthermore, the expansion of invasive plant species is also reducing access to large areas of potentially productive rangeland.

Climatic trends and drought management – analysis of past climate data and predicting future climatic trends in pastoralist areas is characterized by scientific uncertainties. However, at least two bodies of evidence are more certain. First, in some areas pastoralists have adapted the composition of their herds as a response to drought risks and other factors. Increased camel ownership is one example, with camels being known for their drought tolerance. Second, due to trends in human population growth, droughts now have the potential to have negative impacts on people far more than in the past. These impacts include large-scale losses in pastoral herds, which can take many years to recover.



Livestock feed – related to declining access to rangeland as the basic feed resource for pastoral livestock, is the issue of supplementary livestock feed. Although there has been some growth in private sector feed supply in or to pastoral areas, there is still a wide-spread problem of adequate feed for production. Field research in pastoral areas of Ethiopia shows that production in indigenous livestock breeds can improve dramatically with simple supplementary feeding.

Livestock diseases – there is high livestock mortality in pastoral herds of approximately 11% per year, with many of these losses due to preventable diseases. Improvements in disease prevention provide multiple benefits, ranging from more milk available for local consumption, through to more animals available for marketing.

3. Ways Forward

It is widely accepted that to halt and reverse rangeland degradation, and to improve services and livelihood opportunities, substantial additional investment is required in Ethiopia's pastoral and agropastoral area. 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.

Recognising the value of grasslands as carbon sinks, and increasing investment in the rangelands will not only increase carbon sequestration but will also result in improved livestock productivity. It is, therefore, recommended that Ethiopia gives increased attention to carbon sequestration through improved rangeland management practices (including tackling and reversing rangeland fragmentation), a return to local tenure and management systems, and an increase in mobility. Investment in improved rangeland management also has the potential to reduce the impact of droughts. 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 transitioning out of pastoralism.



Complementary support is also needed in the form of strategies to improve fodder supply to pastoral and agro-pastoral producers, and improved veterinary care to reduce losses from preventable diseases. Specific strategies are also needed to prevent further bush encroachment and return large areas of encroached land back to productive rangeland.

As a livelihood system, pastoralism is less understood in the Horn of Africa than sedentary farming, possibly due to policy makers being from farming backgrounds. 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.

Biodiversity and Ecosystem

1. Introduction

In recent years, the issues of biodiversity and climate change have become key issues in Ethiopia. Biodiversity in this document encompasses: wild flora and fauna as well as agricultural crops and livestock. The main environmental problems in the country include land degradation, soil erosion, deforestation, loss of biodiversity (both wild & domestic stocks), desertification, recurrent drought, and flood and air pollution. A large part of the country is dry sub-humid, semi-arid and arid, which is prone to desertification and drought. The country has also fragile highland ecosystems that are currently under stress due to population pressure and associated socio-economic practices. While the causes of most disasters such as drought, famine and flood are climate-related, the deterioration of the natural environment due to unchecked human activities and poverty has further exacerbated the situation. The expansion of agriculture usually takes place at the expense of the natural vegetation, particularly forests, woodlands and other wildlife resources, leading to loss of both flora and fauna, and ultimately, destruction of habitats as a whole. The rate of deforestation due to mainly agricultural expansion and fuel wood gathering is remarkably high. This process has immense impacts on biodiversity and ultimately leads to desertification. Agricultural activities are significant emitters of global greenhouse gases (GHGs) and as such agricultural activity is a major driver of anthropogenic climate change.

Major climate variability such as variability in rainfall (annual and seasonal) affects the correlation of the crops with the seasons and farmers preference and technology involvement to subsequently affect crop biodiversity of a given location. When crop diversity decreases, climate mitigation and adaptation potentials also decrease.

The Government of Ethiopia is making efforts to address these adverse conditions and has designed coping mechanisms. In fact, some of these efforts have brought about strategies that have induced changes in the attitude of the affected local communities. Some strategic measures include the development and implementation of national environmental initiatives, as well as policy/program and project initiatives that directly and/or indirectly address climate change and adaptation mechanisms. These initiatives could

be capitalized for mitigating the undesirable consequences of climate-related hazards.

2. Key Findings of the Biodiversity & Ecosystem group

Key Findings:

2.1. General trends in the impacts of climate change on ecosystems and biodiversity resources:

- Except for some fragmented studies, the review work has found out that there is a major gap in research, and databases are scarce to investigate impacts of climate change, mitigation and adaptation potentials of ecosystems in Ethiopia.
- From the scant data available, almost all of the ecosystems and agrobiodiversities reviewed in this study are found to be vulnerable and affected by climate change.
- The increase in temperature has increased incidence and frequency of fire. Increasing incidence of pests/diseases is also associated with increase in temperature, which is a risk factor in most of ecosystems.
- Generally, climate change is expected to affect ecosystems, species, and habitats in the following ways:
 - Increase in major ecosystem disturbances (ecosystem functions and processes);
 - Shifts in geographical ranges of some native plants and animals;
 - Change in timing of life history events for plants and animals;
 - Spread of invasive species and disease;
 - Degradation and loss of habitat such as loss of stopover and breeding sites for migratory bird species; and
 - Decline in species, populations, genetic erosion, extinction or loss of biodiversity.

2.2. Specific trends/cases in the impacts of climate change on ecosystems and biodiversities

- Ayinekulu *et al.*, (2011) reported high dieback of trees in a dry Afromontane forest, following elevated temperatures during extreme drought conditions.
- Some studies have indicated that the moist montane forest is predicted to shrink from 23.11% under current climate to 22.38% under changing climate (Mamo, 2001). Similarly, dry evergreen montane forest is predicted to shrink from 9.01% under current climate to 1.72% under changing climate (Schmitt *et al.* 2012).
- In Ethiopia, of the 150 Mt CO₂e in 2010, more than 85% of GHG emissions came from the agricultural and forestry sectors (CRGE, 2011). The cultivation of crops contributes to the concentration of greenhouse gases mainly by requiring the use of fertilizer (~10 Mt CO₂e) as well as by emitting N₂O from crop residues reintroduced into the ground (~3 Mt CO₂e).
- According to the report by Girma Megersa (2014) among 18 farmer varieties managed by the farmers so far in the district, 44.4% were lost due to different reasons, 11.1% were rarely produced and only 44.4% are under the production system with different production scale. From the lost varieties, climate change and land degradation played major roles equivalent to the competitive effects of the extension systems in practice. This request calls for the requirement and practices of an interdependent system for conservation of the farmers varieties at field level.

3. Policy implications

3.1. Far more the present attitude/concerns

There is an increasing level of understanding and concern among policy and decision makers on the severity and impact of climate change on environment and biodiversity. The concern is largely esteemed from the multidimensional nature of the impact of climate change to affect the social, cultural, economic and environmental assets. Moreover, the combined effect of this jeopardizes

the present effort to tackle and reduce poverty. Recognizing the fact that the country is currently under the process of transformational changes to bring rapid development, policy and decision makers are now much concerned than before as this transformational changes might have been affected or challenged by the complex nature of climate change.

Therefore, the urgency for policy revisions, new institutional setups and organizational reforms are inevitable and timely. At the onset of this process, it is very crucial to harmonize and align developmental efforts with any of the biodiversity and ecosystem conservation strategies so as to increase the potential of these ecosystems to adapt and mitigate the impacts of climate change.

3.2. Constitutional, institutional and sectoral policy review pertinent to climate change

3.2.1. Constitutional

There are already a number of existing national policy initiatives, sectoral policies, programs and strategies that may directly or indirectly address climate change adaptations and mitigations of the various types of ecosystems in Ethiopia. The Federal Democratic Republic of Ethiopia has already put in place policies, strategies and programs that enhance the adaptive capacity and reduce the vulnerability of the country to climate variability and change. Accordingly, the most relevant policy and program documents for climate change adaptation include Climate-Resilient Green Economy Strategy (CRGE, 2011), Plan for Accelerated and Sustainable Development to end Poverty (PASDEP); Growth and Transformational Policy (GTPI & GTPII).

In the following paragraphs, it has been tried to overlay the policy and strategy frameworks of some of the sectors and institutions, which are thought to have significant roles and stake in designing appropriate climate impact adaptation and mitigation strategies for biodiversity and ecosystem conservation.

3.2.2. Institutional

3.2.2.1. Ministry of Environment & Forest (MEF)

In an effort to realize the Government's Climate Resilient Green Economy

strategy (CRGE), the former Environment Protection Authority (EPA) has been combined with the Ministry of Environmental Protection and Forestry to create the Ministry of Environment and Forest. The ministry is responsible, among other undertakings, to spearhead the reforestation, and other wide-ranging tasks.

3.2.3. Sectoral Policies

3.2.3.1. Environmental Policy

The Environmental Policy of Ethiopia, an umbrella policy composed of 10 sectoral and 10 cross-sectoral environmental policies, has been formulated and approved by the Government in 1997 to promote sustainable socio-economic development through sound management and rational use of natural resources and the environment. The Policy includes implementation issues like institutional coordination, legislative framework and monitoring, evaluation and review provisions. The Policy also emphasizes the need for environmental sustainability to be recognized in other policies and strategies as a key prerequisite.

Climate Change and Air Pollution is among the ten sectoral environmental policies. The overall objectives of this policy are to:

Promote climate monitoring programs as the country is sensitive to changes in climate;

Recognize that a firm and demonstrable commitment to the principle of containing climate change; and

Foster use of hydro, geothermal and solar energy so as to minimize emission of greenhouse gases (GHGs).

3.2.3.2. Ethiopian Biodiversity Institute (EBI)

The general objective of ecosystem-based forest and range land genetic resources conservation is to cope with future climate change risks and to contribute towards a sustainable development of the economic, socio cultural and ecological values of forest and rangeland ecosystems of Ethiopia.

3.2.3.3. Forest Development, Conservation and Utilization Policy and Strategy

A forest policy and strategy is developed with the notion to contribute for the economic growth of the country, maintaining the ecological balance and conserving and enhancing our biodiversity through the sustainable utilization and development of forest resources and community participation.

3.2.3.4. Other sectoral policies

Other sectoral policies such as Science and Technology Policy; Population Policy, Agriculture and Rural Development Policy and Strategy; Water resources Management Policy; Health Sector Development Policy and Program; National Policy on Disaster Prevention and Preparedness; and National Agricultural Research Policy and Strategy are equally important by which CRGE policy should be mainstreamed.

3.3. International commitments

Article 4.9 of the United Nations Framework Convention on Climate Change (UNFCCC) calls for addressing the specific needs and special situations of the least developed countries. In line with this, the Seventh Session of the Conference of Parties (COP 7) established instruments and mechanisms for supporting adaptation, including the establishment of three new funds namely the Special Climate Change Fund (GCF), the Least Developed Countries Fund (LDCF) and the National Adaptation Plan Fund (NAPF) (NAPA, 2007). In addition to the above three funds arranged during COP7, the following international projects support the country's implementing capacity related to climate change:

CRGE; REDD+; FAST Track; GIZ; GGW, UNCCD, IPCC

3.4. Gaps in policies and strategies in executing mitigation and adaptation actions associated with climate change impacts on biodiversity & ecosystems.

3.4.1. Gaps at the policy and strategies level

- Lack of appropriate policy (wetland policy) and regulatory support mechanisms;

- There are mandate and objective overlaps and redundancies (EBI, MEF, etc);
- The country still needs financial and technological support and capacity;
- The priorities of the national policies, sector strategies and programs of the Government are primarily targeted at promoting rural and agricultural development and poverty reduction. As a result, climate change and adaptation issues, associated with biodiversity and ecosystem conservations, are often treated indirectly in sector-specific policies and programs, and
- Gaps related to agricultural intensification strategy, i.e. intensive agriculture has increased area under monoculture and at the cost of mixed cropping and intercropping and this has resulted in loss of species diversity. This trend needs to be reversed.

3.4.2. Gaps at the institutional, sectoral and community levels

- Lack of institutional and sectoral coordination and integration such as discrepancy among sectoral policies (investment/settlement vis-à-vis forestry);
- Inadequacy of cross-sectoral links of ministries and line departments;
- Absence of a center or an institution for research and development (R & D) on climate change adaptation and mitigation;
- Lack of efficient outreach mechanism on environment to local communities;
- Oversight of long-term environmental impacts of short-term economic benefits;
- High level of poverty; and
- Gaps to safeguard and enhancing biodiversity benefits such as: lack of investments on biodiversity resources, lack of integrated land use plan, lack of baseline information, lack of capacity in terms of knowledge and research.

3.5. Policy Intervention Opportunities and Existing Scenarios

- Flexibility in reforming policy and legislations to support climate resilient programs;
- Political willingness and readiness;
- The existing commitments towards transformation;
- The country's forest and biodiversity resources carbon storage and mitigation potentials; and
- The ongoing task of forest inventory, mapping and demarcation activities.

4. Policy Recommendations implied to Ecosystem & Biodiversity mitigation and adaptation actions to climate change.

Based on the policy assessments and review work the following points are recommended:

1. Avoiding duplication of efforts among stakeholders and strengthening coordinated but differentiated responsibilities;
2. Ethiopia has developed a draft Framework National Climate Change Action Plan (FNCCAP). However, the action plan is just a framework that needs further improvement before implementation;
3. Development and enhancement of institutional research capacity both at the national and regional levels;
4. Strengthening public awareness programs on climate change in Ethiopia at the national as well as regional levels;
5. Establishment of a National Environmental Education Program;
6. Regional Capacity Building for Monitoring and Inventorying of Biodiversity;
7. Establishment of a National Research & Development Center for Climate Change;

8. Design an integrated research approach to investigate the nature of climate change impact, mitigation and adaptation potentials of the various types of ecosystems;
9. Develop tools to safeguard and enhance biodiversity benefits;
10. Undertake agricultural policy revision so as to give equal support to the value of crop biodiversity in the farming systems, including access to market information and linkage.
11. 11. Expand seed storage centers and develop genetic management systems for the purpose of seed selection and maintenance of genetic diversity;
12. Strengthen NRM capacity: Institutional and human resources capacity, particularly develop and improve strategies for ecosystems monitoring and management of disturbances such as fire, land use change, settlement, pests, and diseases;
13. Undertake soil and water conservation practices for improved conservations of wetland ecosystems;
14. Community-based sustainable utilization and management of wetlands in selected wetlands in Ethiopia; Identify the different practices of people living in and around protected areas that exacerbate the impact of climate change on biodiversity and ecosystems; and
15. Identify and describe indigenous adaptation practices in the area.

Water and Energy

Water

Ethiopia, the water tower of northeastern Africa

Ethiopia has three principal drainage systems, and 12 major river basins (fig. 1). These rivers carry $ca\ 124 \times 10^9\ m^3\ yr^{-1}$ of water annually. Added to this, groundwater resource of Ethiopia is estimated at between 2.6×10^9 and $30 \times 10^9\ m^3$, and there are 11 freshwater and 9 saline lakes, 4 crater lakes and over 12 major swamps and wetlands. The estimated storage capacity of the major lakes is about $98.84 \times 10^9\ m^3$. Almost all of the major rivers, excepting one, the Awash River, cross the international boundary of the country and are thus international rivers supplying the much needed water to the much drier downstream countries. Hence, the fitting description of the country as the water tower of northeastern Africa.



Figure 1. The major river basins of Ethiopia

Ethiopia's water resource is variable in space and time, certain places and times of the year are dry and water scarce

Although Ethiopia is, relative to many African countries, richly endowed with water, the spatial and temporal distribution of water is highly uneven, making certain places and times of the year very dry and water scarce. The rivers of Ethiopia exhibit typical characteristics of tropical rainfall-dependent flow regimes. Hence, the spatial and temporal distribution of rainfall governs amount and intra-and inter-annual variability of water availability.

Mean annual rainfall ranges from over 2000 mm in some pocket areas in the southwest to less than 250 mm in the Afar lowlands in the northeast and Ogaden in the southeast. Rainfall decreases northwards and eastwards from the high rainfall areas of the southwest. In terms of seasons, in most parts of Ethiopia rainfall is heavily concentrated in *Kiremt*, when 70-80% of the total annual rainfall occurs. This variability in water availability necessitates water storage infrastructure. Given both seasonal and inter-annual variability, significant over-year storage will be particularly important for Ethiopia. However, the current per capita storage of the country is only 160 m³ which is only 20% of South Africa's and 2.6% of North America's. Figure 2 shows the general flow characteristics of some of the Ethiopian rivers, showing very high seasonality.

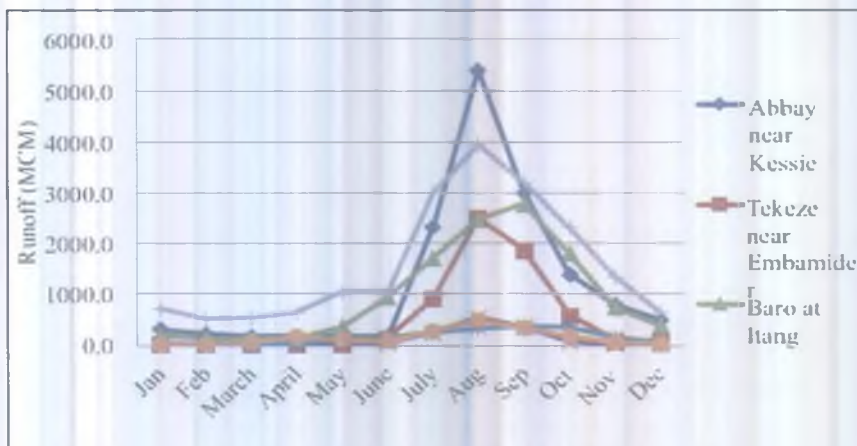


Figure 2. Flow characteristics of some of the Ethiopian rivers, showing very high seasonality.

Following the rainfall pattern, some 70-80% of the annual flow of almost all rivers in the country is from the heavy *Kiremt* rains, and spatially the river basins in the western and northwestern part of the country, namely Abbay, Baro-Akobo, Omo-Gibe, and Tekeze account for about 83% of the country's annual surface water flow, while covering only 39% of the country's land area. To be in contrast, the Wabi-Shebele and Genale-Dawa basins, which drain the southern and southeastern part of the country towards Somalia, cover about 33% of the country and contribute only 7.6% of the total annual surface

water flow. The large spatial and temporal variability, both primarily driven by climatic variability, and the international nature of its most significant surface water resources are major challenges to water resources development and management in Ethiopia.

Ethiopia's water resource is vulnerable to climate change, but also holds the highest promise for national adaptation to climate change

Climate change is exacerbating the natural hydrological variability in Ethiopia, and hence presenting another dimension to the challenge of water resources development and management. Although non-climatic drivers such as land degradation, land use change and agricultural water use play important roles, with changes in climate continuing for the coming century, the type and rate of impacts on water resources is likely to be unprecedented and overwhelming. All changes happening in rainfall and temperature have various effects on available water resources.

Stream flow, available soil water, groundwater recharge and water quality are all vulnerable to the projected changes in rainfall and temperature. For most of the major river basins of Ethiopia, many studies projected reduction of water yield. In general, most studies suggest that in terms of rainfall change wet areas will become wetter while dry areas will become drier. This means that southeastern, northeastern and rift valley areas will become drier; while southwestern, central and parts of western highland areas will become wetter. The reduction of water yield against the slightly increasing rainfall projected for much of the country indicates the effects of increased evapotranspiration loss of water due to the rising temperatures. The findings of some of the available projection studies are presented below as examples.

- A study in the Blue Nile basin estimated 14% reduction of runoff with 3% increase in rainfall and 1.7°C rise in temperature; and 11% runoff reduction with 6% increase in rainfall and 2.6°C increase in temperature. The same study notes that because of the increased runoff in the headwaters to be expected from increased rainfall intensity, it will be less likely that downstream communities will suffer reduction of flow; even with increased water demands and population growth.

- Another study in the Blue Nile basin using 17 GCMs of IPCC 4th Assessment Report found that 11 of the models showed a reduction of flow all along to the end of the century. The same study then notes that there are local differences in the magnitude and direction as well as seasonal patterns of change of stream flows (e.g., figure 3).
- As the climate continues to change, floods and droughts are most likely to become more severe in many parts of Ethiopia. Future Standardized Precipitation Index (SPI) analysis for the Blue Nile basin for different time scales shows that frequency, duration and severity of drought will increase in drier areas, whereas reduced droughts will be expected in the wet areas.
- Future annual flow change varies between -4% and 18% among the GCMs in the watersheds of the Rift Valley Basin as compared to current flows.

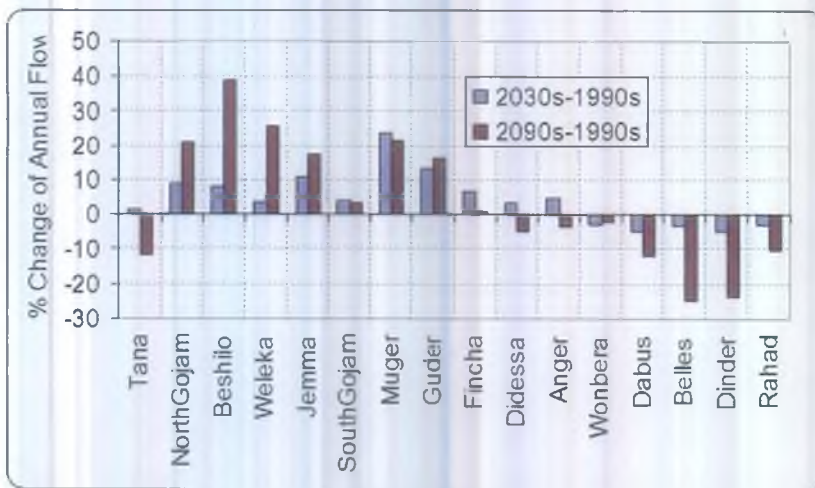


Figure 3. Projected changes in annual flow amounts in the watersheds of the Blue Nile River Basin

Whereas projection-based impact assessment studies report potential declines in water yield, long-term records of stream flows do not show detectable trends for many of the major rivers of the country. For instance, a study of 12 rivers in the Blue Nile Basin detected few changes in low flows,

high flows and low flow indices, and those changes were different in the direction of trends. Figure 4 presents observed variability in the annual flows of 12 rivers in the Blue Nile Basin. In the Awash basin, a study found that there is a reduction of flow amount between 1968 and 1997, mainly because of water abstraction in the upstream. In general, variability and change in flow regimes are more pronounced at small spatial scales than big river basins.

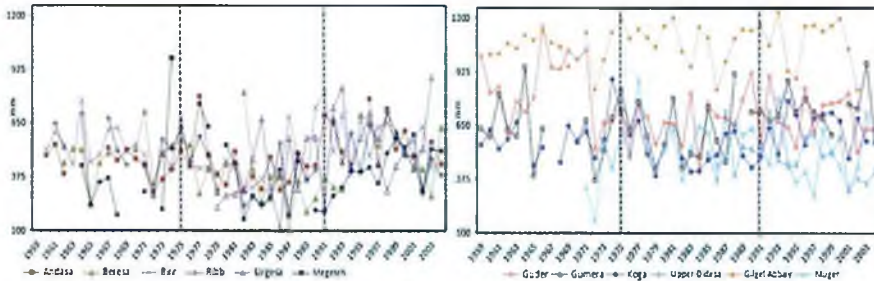


Figure 4. presents observed variability in the annual flows of 12 rivers in the Blue Nile Basin.

Ethiopia’s water resource is vulnerable to climate change, but the sector also holds the highest promise for national adaptation to climate change. This is evident from the central place water-related developments are given in the national Climate Resilient Green Economy (CRGE) initiative and its components such as, the green economy strategy, the agriculture sector climate resilience strategy and the water and energy sectors climate resilience strategy documents.

Ethiopia has designed a water sector climate resilience strategy, the next step is implementation at scale

Ethiopia is currently implementing the CRGE initiative with the objective to protect the country from the adverse effects of climate change and to build a green economy. The CRGE initiative has three objectives: fostering economic development and growth, ensuring abatement and avoidance of future greenhouse gas emissions, i.e., transition to a green economy, and improving resilience to climate change. As a component of the CRGE initiative, a Climate Resilience Strategy has been designed for the water and energy sectors of Ethiopia. The Strategy identifies four sub-sectors and priority actions to be taken under each sub-sector. The four sub-sectors are: (i) irrigation, (ii) water

supply, sanitation and hygiene (WASH), (iii) power generation, and (iv) energy access. The priority actions for the two water subsectors; i.e., irrigation and WASH are: (i) accelerating irrigation development, (ii) enhancing resilience of the rain fed agriculture system, (iii) implementing water demand management, (iv) accelerating universal access to Water, Sanitation and Hygiene (WASH), and (v) improving local water storage facilities or participatory water resource management for improved self-supply of water.

Effective implementation of these priority actions is expected to enable adaptation to the progressive climate change by building resilience into the water resources sector. But implementation of the strategy at scale, including financing, will be a real challenge.

Adaptation to climate change is costly, also barriers and limits exist

The cost of climate change adaptation in the water sector depends on the type and magnitude of future climate changes, drought and flood risk occurrences, and the level of initial water infrastructure in the country. Efforts to quantify economic impacts of climate-related changes in water resources are often hampered by lack of data, particularly in underdeveloped regions like Ethiopia and by the fact that the estimates are highly sensitive to different estimation methods and to different assumptions regarding how changes in water availability will be allocated across various types of water uses, e.g., between agricultural, urban, or in-stream uses.

On the other hand, hydrological changes may have impacts that are positive in some aspects and negative in others. For example, increased annual runoff may produce benefits for a variety of in-stream and out-of-stream water users by increasing renewable water resources, but may simultaneously generate harm by increasing flood risk. Increased runoff could also damage areas with shallow water table. In such areas, a water table rise will disturb agricultural use and damage buildings in urban areas. In addition, an increase in annual runoff may not lead to a beneficial increase in readily available water resources if the additional runoff is concentrated during the high-flow season.

In Ethiopia, the cost required for water management and water sector

adaptation to climate change is expected to be very high due to the very difficult hydrology of the country characterized by extreme events and high inter-annual and seasonal variability, and the poor water infrastructure development. Implementation of the water subsector climate resilience strategy, excluding costs for actions identified as 'cross-cutting,' is estimated to cost USD 291 million. Another study estimates that climate change adaptation in the water sector will cost Ethiopia between USD 158 million and USD 258 million per year. In addition to the financial cost, it is important to note that there are also many other factors, often categorized as physical, political, social and institutional, that limit or complicate adaptation responses and climate risk management activities in the water sector.

Knowledge gaps should not constrain action, but more research and policy attention is needed

There are considerable uncertainties in the projected climate change induced changes in water resources of Ethiopia. Rainfall, the input to water systems, is not reliably simulated in present climate models. There is no good agreement between models to project the future rainfall changes over Ethiopia, although many research outputs have indicated a tendency towards slightly increasing changes. As a result, the nature and extent of how climate change will affect the Ethiopian water sector is not yet well understood. This is a real challenge for policy makers, planners and the community at large to develop long-term water management and climate change adaptation strategies in the water and other water-sensitive socio-economic sectors. Nevertheless, adaptation need not be limited by uncertain knowledge on future climate change impacts. Robust and flexible, no-regrets and low-regrets type adaptation strategies ought to be implemented based on existing information. Along with this, more research into the water–climate interface is required. Some of the key issues, knowledge gaps and research needs related to the climate–water interface and development are:

- Detection and attribution of observed changes in water resources, with particular reference to characteristics of extremes, is an important research priority;
- There is a need for improved understanding of climate change impacts on water quantity, quality and extreme events;

- Impacts of climate change on aquatic ecosystems (not only temperatures, but also altered flow regimes and water levels) are not adequately understood;
- Very little is known about the country's groundwater resource base and the degree of exploitation and utilization for socio-economic activities in the country; and
- Very few studies are available on the economic aspects of climate change impacts and adaptation options related to water resources.

In addition to these important questions for research, there are also a number of developmental issues that require policy attention as the country steps up investments on water infrastructure development. These include;

- Capacity development through short, medium and long-term training at all levels of water governance;
- Development and implementation of training programs in the areas of climate change and its impact on water resources (extreme events, vulnerability and risk, adaptation and mitigation, hydrological modeling, climate change projections, etc);
- Water resources development planning, design and operation activities are constrained by lack of data; hence the need to install standard hydrometeorological equipment and monitor all major watersheds of the country; and

Management of water without managing land is seldom possible; hence the need to strengthen and upscale current efforts at integrated watershed and river basin management in the country.

Water and Energy

Energy

1. Introduction

Energy is crucial to economic and human development. Access to modern, reliable and affordable energy services is a pre-requisite to poverty alleviation, economic growth and social transformation. However, at the global level, the energy system – supply, transformation, delivery and use – is the dominant contributor to climate change, representing around 60 percent of total current greenhouse gas (GHG) emissions. Energy development is not only the contributor of GHG but it is also critically influenced by climate change, arising from anthropogenic emissions.

Ethiopia has taken numerous policy measures to mitigate and adapt to climate changes. These measures are basically based on implementation of the CRGE strategy. The most important part of this strategy in the energy sector is facilitated by improving energy efficiency in energy production (switching from traditional fuel to other renewable energy, consumption, and dissemination of efficient technologies e.g. improved cook stoves). Policy measures were investigated, considering a green development path while climate change mitigation and adaptation were assessed based on the guiding principles of sustainable development, reliable, secure and affordable energy services, impact on reducing GHG emissions and vulnerability to climate change and possible synergies between various measures that may serve both adaptation and mitigation actions.

The Ethiopian Government, in its National Energy Policy, has given emphasis to developing its huge energy resources, especially renewable energy and has diversified its energy mix to enhance supply side that can adequately support economic growth. The commitment of the Government has remarkably brought about rapid expansion of the power infrastructure, increased use and diversity of energy in industry, rapid rise and diversity of energy demand for transport, increased use of off-grid electricity in rural areas and increased use of improved cooking devices in both rural and urban areas (MoWIE 2014). There is also a commitment to ensure appropriate actions to reduce future GHG emissions that will arise from rapid expansion of the energy sector. Measures that are put in place include developing the huge renewable energy resources in Ethiopia as well as deploying more efficient technologies both at the production and end-use levels.

Even though there is a huge commitment by the Government to reduce the energy crisis of the country, unless energy resources are streamlined by a comprehensive and integrated energy policy, sustainability cannot be guaranteed.

2. Key findings

2.1. Availability of huge renewable energy resources:

Ethiopia is endowed with vast energy resources, 30,000 MW hydropower resources, 1387 million TOE biomass resources, 17.5 million TOE agricultural residue, over 100 billion cubic meter of natural gas, 4000MW geothermal energy, 40.3 million tons of coal and oil shale and vast resources of solar, wind and geothermal energy. Ethiopia has made significant progress in recent years in expanding energy access and developing the country's huge exploitable potential of renewable energy resources mainly hydropower, wind, solar, and geothermal. These energy diversifications improve rural development through income generation, job creation, as climate change mitigation and adaptation priority measures to develop climate resilient communities. The energy policy of Ethiopia places high emphasis on renewable energy development and encourages diversification of the energy mix.

2.2. Engagement of the Ethiopian government on Climate-Resilient Green Economy:

To protect the country from the adverse effects of climate change and build a green economy that will help realize its ambition of reaching middle-income status before 2025, the Government of Ethiopia has initiated the Climate-Resilient Green Economy (CRGE) initiative, which follows a sectoral approach. The green economy plan is based on four pillars of which energy is one of them. In the energy sector, the strategic priorities: i) Power generation - diversify the energy mix and improve energy efficiency; and ii) Energy Access - improve efficiency of biomass use and accelerate non-grid energy access, have been identified as response measures.

2.3. Vulnerability to climate change:

The energy sector of Ethiopia is highly vulnerable to climate change, because naturally, the main sources of energy (hydropower and biomass)

are influenced by climate change induced factors such as temperature increase, variable rainfall, extreme floods and extended droughts. To reduce the vulnerability of the sector to climate change, the Ethiopian Government has intervened to increase the adaptive capacity of the sector through: i) Energy diversification by developing renewable energy; ii) Dissemination of efficient energy technologies and avoiding obsolete energy technologies; and iii) Building the capacity of both community and developers.

In order to strike the right balance between climate change adaptation and mitigation measures and also benefit from maximum possible synergies, there is a necessity to examine the issue at hand from multiple perspectives, including realistic expectations of how much the country might contribute to the reduction of GHG emissions, the degree of vulnerability it faces, the need to achieve rapid social and economic development, the interactions with other sectors and the like.

2.4. Inadequacy of Resources:

Ethiopia faces significant challenges of inadequate technology, finance, human and institutional capacity resources to realize mitigation and adaptation measures that are indicated in its relevant policies and strategies. By aspiring to – and achieving – a constructive contribution to the green economy, it is possible to lay the longer-term foundation for reaching middle-income status by or before 2025. Therefore, the planned initiatives and fast-track projects already under implementation need to be strengthened and additional financial sources should be looked for.

3. Policy Implications and Recommendations

3.1. Policy Implications

The main energy policy objective is to ensure the availability, accessibility, affordability, safety and reliability of energy services to support accelerated and sustainable social and economic development and transformation of the country.

A comprehensive energy policy:

- Improves the security and reliability of energy supply;

- Increases access to affordable modern energy;
- Promotes efficient, cleaner and appropriate energy technologies and conservation measures;
- Strengthens energy sector governance and the establishment of strong energy institution;
- Ensures environmental and social safety and sustainability of energy supply and utilization; and
- Strengthens energy sector financing.

3.2. Recommendations

Despite the progress made in formulating Climate Resilient Green Economy (CRGE), National Adaptation Program of Action (NAPA), Nationally Appropriate Mitigation Actions (NAMA), etc., the magnitude of the potential challenge posed by climate change and extreme weather requires additional efforts. Ethiopia's energy production and consumption is based on biomass and hydropower which are vulnerable to climate change. The following recommendations and policy opportunities offer climate change policy makers a valuable platform to integrate policies aimed at expanding sustainable energy access in Ethiopia.

Recommendation #1: Establish clear, consistent and achievable targets for energy development and environmental stewardship.


Presence of clear and consistent energy policy that sets a target for share of renewables into the future is an essential first step. Without such policy mandates, renewable energy development is likely to be unreliable.

Recommendation #2: Implement identified measures.

Identified measures as well as programs and projects considered in the GTP1 that help build mitigation and adaptation potential for the country should be implemented.

Recommendation #3: Implement energy portfolio diversification strategies.

Diverse types of indigenous energy resources should be utilized to increase the capability to switch from one form of energy to another during severe climate change, thereby, building resilience.



Recommendation #4: Develop renewable energy utilization.

More attention should be given to renewable energy resources that are less vulnerable to climate change. Technologies that play significant roles in helping the country mitigate and adapt to climate change should also be scaled-up.

Recommendation #5: Disseminate energy efficient technologies.

Dissemination of efficient energy technologies helps reduce energy demand and therefore increases the adaptive capacity of communities by reducing pressure on forest resources.

Recommendation #6: Ensure new assets are resilient.

For new assets at the design stage, the robustness of design and site locations to climatic variability and projected climate change, including design of energy-generation assets as well as associated infrastructure should be reviewed.

Recommendation #7: Recognize the risks associated with climate change.

Recognizing the risks associated with climate change is a valuable first step towards better planning of new investments in infrastructure and averting potential damage to existing infrastructures. Integration of climate risk considerations in design, siting and operation of energy facilities, through measures such as standards and codes and the review process for replacing or repairing damaged infrastructure are often the cheapest and easiest measures.

Recommendation #8: Build capacity to mobilize local financial resources.

The capacity to mobilize local financial resources, from both public and private sources, as well as leveraging climate finance and other forms of funds available should be developed. Exploring new financing options to improve investments in household-level renewable energy technologies, in addition to existing options that are used by Government for mega projects, will help solve the financial constraints. Experiences in mobilizing local financing for the conventional energy sector could be used for the household-level renewable energy technologies. The mechanisms should take into account the local context with respect to sources and patterns of income, attitudes to

borrowing, availability of micro-credit agencies and ability to repay over long and short-term periods. The Government should build the capacity of both local communities and developers on renewable technologies and climate matters.

Recommendation #9: Develop strategic partnerships.

Strategic partnerships should be developed with countries, companies and private sectors to promote renewable energy technologies, particularly in the rural part of the country.

Recommendation #10: Develop inter-sectoral networking.

Inter-sectoral networking should be developed with other sectors such as water and agriculture that have strong linkage with the energy sector to coordinate and optimize response measures.

Recommendation #11: Establish taskforce for extreme weather conditions.

All levels of government, communities, nonprofit organizations and the private sector must prepare for more extreme weather events, droughts, and altered ecological systems. Dedicated body/taskforce that quickly responds to disasters associated with the extreme weather needs should be established at the national level. The taskforce will respond and take emergency actions at the time of high damage on energy infrastructure.

Recommendation #12: Build institution for capacity.

It is imperative to create an institution which is entrusted with policy formulation, priority setting and coordination of all energy sector development activities in order to coordinate and ensure consistency in energy resource development, and to avoid resource waste and duplication of efforts.

Recommendation #13: Encourage small-scale renewable energy adoption, scaling up opportunities offered by energy technologies.

The low-level of energy access in Ethiopia requires significant attention to be paid to solving the energy access problem. For the majority of population, with limited grid access, small-scale technologies can offer feasible solutions to provide modern energy services. Energy technologies that rely on wind, solar and biomass resources are increasingly attractive alternatives. Large-

scale application potential of these alternatives should be encouraged through supportive policies.

Recommendation #14: Recognize the interdependencies among broader access to clean energy services, climate change mitigation and adaptation and social development.

Action needs to be taken to enhance policy coherence and integration in these related fields. Policies that treat energy, climate change and sustainable development separately are unlikely to fully leverage synergies offered by their interplay. If there will be a global consensus around a climate change target, these relationships are even more pronounced. Policy makers should evaluate their current policies and innovatively integrate and harmonize cross-sectoral policies.

There remain numerous challenges to effectively tackle the energy problem of Ethiopia. Climate change-related impacts will also continue to pose serious risks to social development. However, policy makers have a wide array of policy options and effective instruments to pursue a coherent and integrative energy and climate change policies that can start to point in the right direction. Renewable energy technologies such as solar energy, wind energy, geothermal, bioenergy, waste/biogas and hydropower are increasingly competitive alternatives, but will need to be leveraged innovatively with other broader societal goals.

Health and Settlement

Key Messages

The Health sector is affected by climate change and weather variability. This includes morbidity and mortality due to climate sensitive diseases, health infrastructure damage and shift of resources to respond to health crisis related to weather variability and climate change. The most common climate change-related effects on health in Ethiopia are morbidity and mortality due to vector-borne diseases. However, new conditions may emerge under climate change, and existing diseases may extend their range into areas that are presently unaffected. But the largest risks will apply in populations that are currently most affected by climate-related diseases.

If climate change continues as projected until mid-century, the major increases of ill-health compared to no climate change will occur through: greater risk of injury, disease, and death due to more intense heat waves and fires, increased risk of under-nutrition, resulting from diminished food production in poor regions, consequences for health of lost work capacity and reduced labor productivity in vulnerable populations, increased risks of food- and water-borne diseases and vector-borne diseases.

Strategies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building, should be devised and properly taken into account to reduce the impact of climate change on health. The most effective adaptation measures for health in the near-term are programs that implement basic public health measures such as provision of clean water and sanitation, secure essential health care, including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty.

Introduction

Ecosystems are essential to human well-being and especially to human health. Health risks from climate change are expected to increase. Human activities are responsible for an annual emission of an estimated 7.9 billion tons of carbon dioxide to the atmosphere. Global Green House Gases emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (IPCC, 2007). Continued emissions at, or above, the current rates would cause further warming and induce many changes in the global climate system during the 21st century, that would very likely be larger than those observed during the 20th century. For the next two decades, a warming of about 0.2°C per decade is projected for a range of Special Report on Emissions Scenarios. Even if the concentrations of all the gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected (Sambo C., 2011).

Early evidences indicated the association of climate change and variability and human health. The current understanding related to warming of the globe is known to be manifested in the form of increases in extreme events, increases in temperature, decreases in rainfall and increases in sea-level. Climate experts are particularly confident that climate change will bring increasingly frequent and severe heat waves and extreme weather events, as well as a rise in sea levels.

Thus, policy supporting adaptation has been a base as a necessary strategy for responding to both climate change and supporting development, making adaptation pivotal in all aspects. This will help to curb the health impacts of climate change in the setting of Ethiopia.

Adaptation strategies that help to engage communities at the centre of health impacts of climate change and variability as well as stakeholders engaged in taking the leading role in taking practical steps towards adaptation and mitigation within enabling policy environment is urgently needed.

2. Key findings

2.1. Health impacts of climate change and variability

The health impacts of climate change and variability are well documented. Despite the presence of local variability in distribution and magnitude of potential health impacts, generally climate change is believed to bring the following health effects such as heat-related morbidity and mortality; weather-related morbidity and mortality; asthma, respiratory allergies, and airway diseases; food/water and vector-borne and zoonotic diseases; cardiovascular disease and stroke; nutrition diseases and human developmental effects; mental health and stress-related disorders; neurological diseases and disorders; and cancer. These could be categorized into three major categories: direct impacts, which relate primarily to changes in the frequency of extreme weather, including heat, drought, and heavy rain; effects mediated through natural systems, for example, etiologic agents, animal reservoirs of disease vectors, water-borne diseases, and air pollution; effects heavily mediated by human systems, for example, occupational impacts, under nutrition, and mental stress.

In Ethiopia, climate change and variability is known to be the underlying cause of food insecurity, arising from occurrences of droughts and floods; outbreak of diseases such as malaria, dengue fever, water-borne diseases associated with floods and respiratory diseases associated with droughts; land degradation due to heavy rainfall; damage to communication, road and other infrastructure by floods; droughts and floods.

2.2. Vulnerability to disease and injury

The impact of injuries due to climate variability and climate change depends on the degree of vulnerability of the society. Vulnerability is a function of both exposure to changes in climate and the ability to adapt to the impacts associated with that exposure.

Population vulnerability to health impacts occurs in four ways: social, economic, technological and demographic. Causes of population vulnerability to ill-health, in the face of environmental stress, also include the level of dependency and geographical isolation. By stretching limited social resources

across a broader range of health and other problems, climate change may affect the implementation of public health and nutrition programs.

Some of the very important parameters that determine the vulnerability status include geographic causes, health status, age and gender, socioeconomic status, public health and other infrastructure. Vulnerability due to population growth which leads to decreasing resources, increase among aged people, increase in overweight people, chronic draught and governmental instability will continue unless urgent actions are taken.

Future trends in social and economic development are critically important to vulnerability. For instance, countries with a higher Human Development Index are less affected by floods, droughts and cyclones (Patt et al., 2010). Therefore, policies that boost health, education, and economic development should reduce future vulnerability.

2.3. Direct impacts of climate and weather on health

Evidence showed that climate change is likely to cause increased heat-related mortality. Extremes of temperatures, both hot and cold, can cause physiological disturbance and organ damage leading to illness or death.

The impacts of heat-related mortality vary with age and socio economic status. Thus, the elderly, the very young, persons with impaired mobility, and persons suffering from cardiovascular disease are most affected by such weather extremes. In addition, socioeconomically deprived segments of urban populations are also relatively more vulnerable to the impact of heat waves, which is considered to be due to poor housing conditions, lack of access to air-conditioning, and greater response to the urban “heat island effect” (McMichael et al., 1996). Climate change is expected to exacerbate the health impacts of heat through rising temperatures and higher frequency and severity of heat waves.

Extreme weather events, such as floods and storms, are other effects of climate change and, evidence has shown that in Ethiopia flooding is one of the principal and frequent outcomes of climate change that inflicts human health. The number of flood-related deaths in Ethiopia has increased steadily from 199 in 2003 to 932 in 2006 (Samson *et al.*, 2009). The same authors

reported the rise of diarrhea and malaria incidence as well as damage to crops and inundation of farm land, which can lead to food shortages which in turn may lead to malnutrition, with an estimated damage to 1,650 ha of maize crop, and consequently a 20% reduction in production. Most of the people affected by flood were very poor and considered highly vulnerable in terms of food security. Though it is difficult to relate flooding to nutritional status without undertaking prior surveys, it is likely that shortage of food caused by flooding in Ethiopia exacerbated existing malnutrition in the country.

If the frequency of extreme weather events increases, deaths, injuries, stress-related disorders and many adverse health effects associated with social disruption, enforced migration and settlement that those events entail, would also increase. The impacts of extreme weather events would be greatest on communities with limited technical and social resources (McMichael et al., 1996).

2.4. Ecosystem-mediated impacts of climate change on health outcomes

Some of the ecosystem-mediated impacts of climate change on health outcomes could be vector-borne and other infectious diseases, food- and water-borne diseases and health outcomes from poor air quality.

The tropical African climate is favorable for most of the vector-borne diseases. Some of these diseases are malaria, schistosomiasis, onchocerciasis, trypanosomiasis, filariasis, leishmaniasis, plague, Rift Valley fever, yellow fever and tick-borne hemorrhagic fevers. Climate not only determines spatial and seasonal distributions but also influences inter-annual variability, including epidemics and long-term trends.

The upper altitudinal limit of malaria transmission was known to be 2000 meters above sea level (masl) (MCP, 1983). Nevertheless, there has been ample evidence that confirmed the encroaching of endemic malaria to high altitudes above 2,000 m and as high as 2,200 masl, respectively (Tulu, 1996; Woyessa *et al*, 2004; Tesfaye *et al*, 2011; Woyessa *et al*, 2012). In support to this evidence, an average increase in the daily minimum temperature of 0.4°C *per* decade for three decades has been recorded in Ethiopia (Conway *et al*, 2004). Additional evidence showed the regional climatic variability/change

in the last three decades. For instance, a rise of all temperature variables by 0.2°C *per* decade was observed in the Kenyan highlands since 1979 (Omumbo *et al.*, 2011).

Expansion of malaria is more pronounced at the borders of malaria-endemic areas and at higher altitudes within malarious areas Martenset *al.* (2005). Another recent study projected that highlands of Ethiopia and Zimbabwe will likely experience rise of malaria incidence closer to their upper limits of transmission cut-off (Tanser *et al.*, 2003). This implies that areas free from malaria transmission due to low temperature located at high altitudes might experience endemic malaria in the future. According to projections in the past, the highland areas of Ethiopia and Zimbabwe are among those with expected rise of malaria incidence in higher altitudes.

In tropical and subtropical areas throughout the world an estimated 2.5 billion people are at risk of dengue fever (WHO, 2008). From 1975 to 1996 Ethiopia has been among dengue-endemic countries (van Kleef *et al.*, 2009). Additionally, a recent review has shown that dengue was present in Ethiopia. Although there is lack of evidence and impacts of climate can't be quantified, it is assumed that climate trends will have exacerbated the effects of other factors, at least in some areas (van Kleef, 2009). Similarly, tick-borne diseases and other vector-borne diseases, like trypanosomiasis endemic to Ethiopia, are affected by climate change.

Another health impact of global warming is the rise of food- and water-borne infections as a result of increase in the frequency and intensity of both floods and droughts. Thus, disease transmission may be enhanced through the scarcity and contamination of potable water sources. According to the World Health Organization (WHO), almost 90% of the burden of diarrheal disease is attributable to lack of access to safe and adequate water, sanitation (WHO, 2009a). Additionally, reductions in the availability and reliability of fresh water supplies are expected to amplify the disease burden. Previous estimations showed that 1.1 billion people do not have access to safe and adequate supplies of safe water, and 2.4 billion people do not have access to adequate sanitation (WHO, 2009b). Thus, under global warming situation, the prevailing shortage of safe water might be exacerbated mainly in developing countries. Globally, childhood diarrhea is already a major cause of premature

mortality. Under deteriorating conditions of water qualities, epidemics of cholera, typhoid, and similar diseases can be expected (Hunter, 2003). The most evidence of the effect of temperature on risk from water-borne disease is in relation to cholera.

Yellow fever is among the deadly infectious diseases that affect tropical regions of South America and Africa. It is estimated that 200,000 cases of yellow fever occur annually, resulting in about 30 000 deaths. Of those 90% of cases occur in Africa. In East Africa, yellow fever remains a disease of increasing epidemic risk. For example, Uganda (late 2010), Sudan (in 2003 and 2005) and Kenya (1992-1993) yellow fever outbreak was reported by the WHO (WHO, 2013). In most of the cases, the epidemic occurred after several years of absence, 2-5 decades. Ethiopia is also among the East African countries stricken by yellow fever outbreak in 2013 (EPHI, 2013 unpublished report). The outbreak attacked areas in Southwestern Ethiopia, and similar areas where outbreak has been reported between 1959 and 1962.

Despite the presence of tools for diagnosis, vector control, vaccine and surveillance system for yellow fever the endemic countries had extremely poor or inadequate implementation of programs. In addition, the global-warming concomitant effect immensely contributed to the high reproduction rate and the capacity of insect vectors to establish and to adapt to new environmental conditions. Air quality is also another important parameter causing significant cases and deaths in Ethiopia.

2.5. Health impacts heavily mediated through human institutions

Nutrition, occupational and mental healths are some of the health impacts accounted here. Under nutrition remains one of the world's most serious, but least addressed socioeconomic and health problems (FAO, 2010). Climate change affects food and nutrition security and further undermines current efforts to reduce hunger and protect and promote nutrition. Additionally, under nutrition in turn undermines the resilience to shocks and the coping mechanisms of vulnerable populations, lessening their capacities to resist and adapt to the consequences of climate change. In Ethiopia, malnutrition particularly under nutrition, is one of the public health problems. Climate

change directly affects food and nutrition security, undermining current efforts to address under nutrition.

Occupational health is one of the key public health issues related to work place, including in industries. Heat stress and heat stroke are the most serious issues that cause death in work places. Climate change increases heat stress and consequently reduces work capacity. The effect of heat on occupational health and safety also includes death of exposed individuals. A study by the National Oceanic and Atmospheric Administration found out that work capacity has already reduced by 10% during extreme heat in summer months, which is likely to double to 20% by 2050.

In Ethiopia, there is a high under reporting of accidents occurring at work places. A total of 6153 work-days were lost, at an average of 11.4 days per injured worker per year. A study that projected future effects of heat on work capacity showed that, in 2050, more than half the afternoon work hours will be lost due to the need for rest breaks, in Southeast Asia. At least up to 20% loss of productivity globally will occur by 2100 due to reductions in labour capacity from heat stress under climate warming.

Mental health is another public health dimension exacerbated due to harsher weather conditions such as floods, droughts, and heat waves. These conditions tend to increase the stress on all those who are already mentally ill and healthy ones through creating sufficient stress. Violence and conflict are also important security issues exacerbated by climate change.

Climate change also raises concerns regarding human security. There are studies claiming that water and climate-related conflict may result from scarcity of water resources, a situation that may become more frequent or severe through climate change (Clico, 2012). According to a document, in Ethiopia, drought and famine have been powerful factors in shaping governance over the past 40 years (USAID, 2011).

3. Policy implications

With the present understanding of health impacts of climate change and variability the Government of Ethiopia should focus on creating an enabling policy environment to affected communities and stakeholders engaged to take part at all levels of adaptation to and mitigation of climate change.

Two policy options, including adaptation to protect health from climate change in the health sector itself and other sectors outside health are briefly presented here. However, both options are interconnected and therefore they should be considered together. Health is a cross-cutting issue, serving as a base for the development of a country. A healthy nation would be productive and prosperous and vice versa.

With broader concepts adaptation to climate change and variability is important both for impact assessment and for policy development. At present, adaptation to climate change and its impacts is receiving increasing attention as an alternative or complementary response strategy to reducing net emissions of greenhouse gases (mitigation).

Policy option 1: Inside health sector

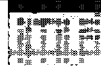
On the basis of a summary of available evidence generated at local, there is strong community-based health access especially in promoting and advocating health at the household level. Thus, taking advantage of this enabling factor the quality of health care at curative and supplying health commodities as well as fulfilling motivated workforce is critically important. This step should be taken in the health sector by taking two key steps: improving basic public health and health care services and early warning systems.

Policy option 2: outside the health sector

The role of other sectors in health adaptation is a vital component at the national level. Thus, identifying roles and responsibilities as well as prioritizing key areas with phase-based approach helps to harmonize and align efforts in the adaptation and mitigation approach. There is a need to mainstream adaptation and mitigation strategies across key sectors affected by climate change and variability. Other sectors with key role to play in adaptation and mitigation activities are: agriculture, water resource, energy and irrigation as well as road transport.

Recommendations

The Government of Ethiopia could focus on making health a priority area in the current development activities through mainstreaming of adaptation to



and mitigation of climate change. The country's strategy of green economy and climate change resilient society should encompass identifying a national research agenda related to areas with no current research evidence and aligning of efforts to avoid overlapping of roles and responsibilities as well as areas undermined.

Industry,Transport and Infrastructure

1. Introduction

The GHG emissions from industry, infrastructure and transport policy instrument in Ethiopia have been found from relevant national policy documents, publications and case studies. In addition, the reviewed policy documents and legislations addressed the impact of transport, industry and infrastructure emissions on the ambient air quality and the environment. From these work attempts were made to summarize policy issues, addressing GHG and pollutants emission from transport, industry and infrastructure in Ethiopia.

The Ethiopian population is experiencing climate change and its impacts on the environment and natural resources; extreme weather events, rise in temperature, decline and variation in rainfall, and e.t.c. Agriculture is the source of livelihood to an overwhelming majority of the Ethiopian population and is the basis of the national economy. A decrease in seasonal rainfall has devastating implications on agricultural production leading to food insecurity (Ekbom 2013).

The Government of the Federal Democratic Republic of Ethiopia has initiated the Climate Resilient Green Economy (FDRE 2011) initiative to protect the country from the adverse effects of climate change and to build a green economy that will help realize its ambition of reaching middle-income status before 2025 (FDRE 2010).

The main objective is to identify green economy opportunities that could help Ethiopia reach its ambitious growth targets while keeping greenhouse gas emissions low. The Government intends to attract development partners to help implement this new and sustainable growth model.

The Government will also take measures to put the other industrial sub-sectors on a sustainable economic development path. Industry is the sector with the highest growth in GHG emissions up to 2030. Under business as usual assumptions, emissions will rise from the current level (4 Mt CO₂e in 2010) to 71 Mt CO₂e in 2030.

In this summary report, the comprehensive policy analysis (policies, legislations, standards and codes) necessary to create an enabling

environment for transition to inclusive, low emission climate resilient green industrial development in Ethiopia, were addressed.

2. Industry policy

Among the industry sector, the single most important driver is the cement industry, followed by the chemical industry and steel/engineering. The emissions of the industry sector are essentially driven by the volume of production in each industry and the emission factors per unit of production. The Industry sector has identified and evaluated 37 abatement levers for 12 industry segments, with a total gross abatement potential of 22 Mt CO₂e in 2030.

The vast majority of the emissions growth and abatement potential is in the cement industry, which has a gross abatement potential of 16 Mt CO₂e.

The majority of the abatement levers fall under the following headings:

1) Energy efficiency (e.g., retrofitting factories with modern production technologies; improving insulation, recovering waste heat, and using cogeneration), 2) Alternative fuels (e.g., switching from coal/furnace oil to biomass/biofuels or electricity), 3) Alternative production processes (e.g., replacing chemicals with enzymes, clinker substitution), 4) Carbon capture and supply to other industries which use carbon as an input into their production process; mineralization.

By integrating climate and development planning, policies and actions comprehensively across these multiple sectors, low-carbon development clearly avoids the mistake done by developed countries and considered to simultaneously mitigate carbon emissions, accelerate or maintain economic growth. In order to ensure this development path, among other things, policies, regulations and procedures are needed that support and incentivize actors to move towards the designed strategy.

2.1. Environmental Policy of Ethiopia

Environmental Policy of Ethiopia has been issued by the Environmental Protection Authority in collaboration with the Ministry of Economic Development & Cooperation, Government of Ethiopia dated April 2,1997 has

the overall policy goal as: to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

Key Environmental Policies relevant to Industrial sector are Control of Hazardous Materials and Pollution, Atmospheric Pollution and Climate Change and Environmental Impact Assessment (EIA).

2.2. Environmental Standards

The environmental standards prescribed by EPA for Industrial Pollution Control in Ethiopia include: i) Standards for Specified Industrial Sectors, ii) General Standards for all other Industrial Effluents, iii) Standards for all other Industrial Gaseous Emissions, and iv) Standards for Noise limits.

The limit values specified in the Standards apply to the emissions to atmosphere, emissions to water and noise.

2.3. Recommendation

- Total carbon dioxide emissions, both from fuel and process, increased drastically and reached 3.32 million metric ton in 2006 E.C. Between 2003 and 2006 E.C both clinker production and CO₂ emission has shown 300% increment due to a number of newly constructed operational small cement industries. This trend will continue to rise when the six cement industries under construction becomes operational. Therefore, the policy implementations should be strictly enforced by the regulatory bodies.
- From the review of the document it is clear that effective CO₂ reduction policies focuses only on energy efficiency and fuel substitution, but has to address process emissions as well.
- Policy makers in Ethiopia must combine a number of separate elements into a coherent and consistent whole. Since, the ultimate objective of industrial policy is development in the much wider socio-economic sense, the attainments of a country in industrial development must

then be made both in terms of the degree of success in generating industrial development as to, its contribution to enhancing socio-economic development.

- It is important to integrate climate and development planning, policies and actions comprehensively across the multiple sectors, low-carbon development clearly avoids the mistake done by developed countries and considered to simultaneously mitigate carbon emissions, accelerate or maintain economic growth. In order to ensure this, policies, regulations and procedures are needed to support actors to move towards the designed strategy.

3. Transportation Sector policy

Many countries in Africa have put in place legislations for the protection of the environment. An important provision of these laws is a requirement for project sponsors/developers to undertake environmental impact assessments (EIA) for proposed projects before they are implemented. In addition to the national environmental laws, a number of these countries, including Ethiopia, Egypt, Nigeria, Tanzania, South Africa and Uganda have also developed supporting regulations and sectoral guidelines for the implementation of these policies and laws (UN-ECA, 2009).

3.1. Transport policy directions

The National Transport Policy (Draft-unpublished) (Ministry of Transport, 2011) recommends the following policy directions for the transport sector regarding the environment:

- i) Minimize any negative environmental impacts arising from transport infrastructure construction, maintenance and the provision of its services, ii) Minimize traffic-generated pollution in urban areas, iii) Establish enforcement systems, and iv) Establish transport sector environment unit.

3.2. Strategies to achieve policy objectives

The draft National Transport Policy paper (Ministry of Transport, 2011) identifies the following strategies to achieve the policy objectives regarding the environment:

a) Ensure environment impact assessments as key requirements in transport projects and in implementing mitigation measures, b) Promote the use of efficient and less polluting modes of transport, c) Encourage non-motorized transport interventions to mitigate adverse effects, d) Promote fuel economy standards for motor vehicles, e) Encourage use of alternative fuel and energy sources, f) Resolve traffic flow bottlenecks at intersections and make them efficient, using traffic signals and modern technologies to deliver standard services, and evaluate the use and implementation of interchanges, roundabouts and other options, g) Expand pedestrian walkway network, construct segregated bicycle and pedestrian paths from other traffic, use cobble stone and other appropriate technologies for the construction of pedestrian paths, build underpass or overpass on high traffic volume major roads, h) Relocate the freight depots from the center to the outskirts of the ring road so that trucks will be serving there for loading and unloading services.

The government will promote the use of minimized transportation related to air emissions and discharges of contaminants to surface and ground water, and minimize the generation of waste through each phase of the life cycle of transportation vehicles and infrastructure. The draft National Transport Policy indicates that the Government will take up major share of City Bus Services as well as extensive work programs for improvement of current public bus transport, reduction of traffic jams and improvement of the environment (Ministry of Transport, 2011).

3.3. Policy recommended by for transport sector

1). Mandatory requirement of fuel efficiency and emission certificate for vehicles to be imported or assembled in the country, 2) Banning of the import of old second hand vehicles older than 8-10 years, 3) Introduction of hybrid and electric vehicle with duty free import, Improvement of maintenance infrastructure of vehicles and increasing awareness, 4) Amending the Ethiopian fuel standard for limiting sulfur to 50 ppm maximum in diesel fuel, 5) Preparation of incentive package to promote biodiesel production such as VAT exemption, 6) Legislating all vehicles to be imported or assembled in the country to have catalytic converters that confirm at least to Euro III emission

standard, and 7) Legislating that all three-wheel vehicles shall have four stroke engines and a catalytic converter 8) Introduction of mass passenger transport system in urban areas such as buses and light rail system (Ministry of Transport, 2011).

4. Infrastructure and Urban Planning

The policy also emphasizes a strategy to minimize the impact of urban transport and mitigation the environment pollution in urban centers, by taking actions that would enable the urban centers to be clean from air and sound pollution. In order to fulfill this, the Government will focus on the quality of petroleum importation and specification of vehicle importation and book value of operational vehicles in accordance with their age or economic life (Ministry of Transport, 2011).

One of the objectives of the ministry of transportation is to ensure coordinated implementation of the city development plan and transport infrastructure and service plan, promote interdependent overall city and urban transport development. In line with this objective, it has identified the following policy directions:

Ensure the connectivity between the city development and the transport plans during their preparation and implementation period, 2) The future development direction of the city shall take into account the transport infrastructure and mass transport service, 3) To minimize trip length and avoid unnecessary trips through local development plan that connects residential areas with work places, schools, market places and other social services, 4) Given attention to non-motorized transport in the preparation of the master plan and road plan of the city and its implementation to address the large size pedestrian walkways in the city, 5) Environmental protection, transport planning and implementation shall be integrated in order to ensure healthy transport infrastructure and service, 6) Conditions shall be facilitated to reduce or avoid air pollution caused by transport infrastructure construction and services.

The Addis Ababa Transport Policy (Ministry of Transport, 2011) sets out the following strategies as a means to achieving its policy objectives:

1) Induce densification by developing central business district areas where there is adequate transport infrastructure, access to mass transport, businesses, government institutions and social services, 2) Constructions undertaken by public or private property developers that generate high-traffic volume shall be aligned with high-standard load capacity roads, 3) Access to social institutions that render public services with road and mass transport, 4) Develop work areas, market places and social institutions around residential quarters to minimize unnecessary long trips, 5) Study and implement sideline activities that enable to reduce or prevent negative influence on the surrounding areas during transport infrastructure construction and maintenance.

