

Climate Change Vulnerability and Risk Assessment of Agriculture and Food Security in Ethiopia

Which Way Forward?

Working Paper No. 59

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Edited by Henry Mahoo, Maren Radeny, James Kinyangi, and Laura Cramer



RESEARCH PROGRAM ON
**Climate Change,
Agriculture and
Food Security**



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Abstract

To raise awareness on climate change and food security, and to understand the needs for research and priorities for agricultural adaptation and mitigation in Ethiopia, the Climate Change Forum – Ethiopia (CCF-E), the Ministry of Agriculture, USAID Ethiopia and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) East Africa organized a two day national conference in July 2011, in Addis Ababa. The objectives of the conference were to:

- Review and assess the vulnerability and risks to Ethiopian agriculture as a result of climate change;
- Explore the threats faced by Ethiopian agriculture as a result of climate change;
- Identify gaps and opportunities in addressing the challenges of climate change; and
- Create a plan for integrating adaptation and mitigation actions and policies into the national framework.

Thirteen papers were presented at the conference on a range of topics. The recommendations from these papers provide a solid framework for the Ethiopian government to improve its climate change policies and enhance its research in critical sectors and regions. The groundwork has been laid through such documents as the Climate Resilient Green Economy mission statement and the Ethiopian Programme of Adaptation on Climate Change. Enhancing capacity in key sectors such as agro-meteorological advisories and downscaling climate change models, improving agricultural extension services especially for women, increasing research in new crop varieties, and creating policies to allow mobility of pastoralists are all key areas which can help reduce the vulnerability of Ethiopian agriculture to climate change.

Keywords

Climate change; risk assessment; vulnerability; agriculture; Ethiopia.

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We acknowledge the contribution of Catherine Mungai of CCAFS East Africa and Michael Karinga for editorial input and layout and sincerely thank all the conference participants.

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1. Introduction

Major economic sectors in sub-Saharan Africa are highly vulnerable to climate change and climate variability, with huge economic impacts. Agriculture remains the economic mainstay of many countries in sub-Saharan Africa, employing about 60% of the workforce and contributing approximately 30% of gross domestic product (GDP) (Thornton et al. 2011). In East Africa, the agricultural sector provides livelihoods to 80% of the population and contributes about 40% of the GDP. Consequently, climate change and variability and the increasing frequency of extreme climatic events such as floods and drought in the region are threatening the food production systems, livelihoods and food security of hundreds of millions of people. In addition, existing developmental challenges such as rapid population growth, widespread poverty and inequality, poor governance, and conflict and civil strife aggravate the region's vulnerability and in turn contribute to low adaptive capacity.

Ethiopia's economy is highly exposed to climate change and variability. Agriculture forms the basis of the country's economy contributing about 40% of the GDP and employing 85% of the population (Byerlee et al. 2007). The rainfed nature of Ethiopia's agriculture implies that agricultural production is sensitive to fluctuations in rainfall. Climate projections for Ethiopia show continued warming, but very mixed rainfall patterns (Conway and Schipper 2011). The main effects of climate change on crop production will be changes in regular crop planting times, length of growing season, and shifts in suitable crop types or cultivars.

Ethiopia is extremely vulnerable to drought, floods, heavy rains, frost and heat waves (NMA 2007). The greatest loss of life associated with drought in Ethiopia occurred in 1984, 1974 and 1973. In 2002, about 14.2 million people (over 20% of the total population) were affected by drought (World Bank 2007). Again in 2011, the severe drought in the Horn of Africa affected nearly over 3 million people, mainly in Ethiopia. According to the World Bank climate risk fact sheet of 2011, more than half of all households in the country experienced at least one major drought shock between 1999 and 2004. While floods have historically not been a major climate risk in the country, Ethiopia experienced devastating floods in 1997 and 2006 (Tarhule 2005, Conway et al. 2009). These climate-related disasters, particularly

drought, have significant negative impacts on agriculture, rural livelihoods, food security and economic development.

To raise awareness on climate change and food security, and to understand the needs for research and priorities for agricultural adaptation and mitigation, the Climate Change Forum – Ethiopia (CCF-E), the Ministry of Agriculture, USAID Ethiopia and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) East Africa organized a two day national conference in July 2011, in Addis Ababa. The objectives of the conference were to:

- Review and assess the vulnerability and risks to Ethiopian agriculture as a result of climate change;
- Explore the threats faced by Ethiopian agriculture as a result of climate change;
- Identify gaps and opportunities in addressing the challenges of climate change; and
- Create a plan for integrating adaptation and mitigation actions and policies into the national framework.

Conference participants included over 150 decision makers from regional and federal governments, experts from research institutions and universities, and practitioners from civil society organizations and the private sector. The conference was officially opened by His Excellency Mr. Sileshi Getahun, State Minister, Ministry of Agriculture of Ethiopia. Thirteen papers were presented at the conference focusing on the status of Ethiopia's agricultural sector, analysis of gaps between available climate information and needed information, identifying policies to support adaptation and mitigation, and exploring opportunities to harness best practices in sustainable land use and water management. The papers have been compiled into this proceedings document and can be used to inform future research and policy agenda.

The collection begins with a summary of the impacts that climate change will have on crop production in Ethiopia, contributed by Adefris Teklewold, Girma Mamo and Habtamu Admassu of the Ethiopian Institute of Agricultural Research. They present the vulnerabilities and risks for crop production posed by climate change, assess best practices and adaptation strategies, and identify knowledge gaps in managing risk and reducing vulnerability of crop production to climate change. This is followed by an assessment of trends in agricultural input use and the implications for climate change adaptation and mitigation in Ethiopia by Techane

Adujna of the United Nations Development Programme. Adujna discusses the trade-offs inherent in the dual goals of increasing food production and achieving a green economy. Efforts to increase the use of chemical fertilizers to achieve food security among the Ethiopian population should be balanced with efforts to minimize its negative impacts.

Water management is addressed next in the paper by Hune Nega of the Ministry of Agriculture. Water scarcity is projected to increase under climate change, and actions must be taken to improve agricultural water management. The Ethiopian National Adaptation Programme of Action (NAPA) includes large and small-scale irrigation, rainwater harvesting and water efficient technologies. Nega reviews the current situation and presents Ethiopian experiences on selected agricultural water management practices for adaptation to climate change. Land management practices also need to be considered under adaptation to climate change. Daniel Danano Dale explains in his paper why, despite great efforts and investments made by the Ethiopian government in the past, sustainable land management practices are largely not in use. He covers a bevy of technologies, practices and approaches that have been reviewed for scaling up. Improving land management is critical in the face of climate change as it contributes to declining agricultural productivity, depleting water resources, and food insecurity.

Another key factor in adapting to climate change is the availability of agrometeorological information for use by farmers. Tesfaye Gissila of the National Meteorological Agency provides a detailed review of the current climate services in Ethiopia and presents a general framework of how agrometeorological advisory services can be integrated into the country's agricultural extension service to help inform climate change adaptation activities.

This is followed by Gemedo Dalle's synopsis of the effects that climate change will have on transboundary issues in East Africa. Climate change causes shortages of food, water and other resources leading to human migration, environmental degradation and resource depletion and sometimes to violent conflicts. The changing climate is threatening the sustainability of the livelihoods of people living in Ethiopia and across its borders. Nations must take structural measures to prevent conflict, reduce livelihood vulnerabilities, and conduct environmental diplomacy to avoid serious conflicts. Many of those affected are pastoralists living in southern and south-eastern Ethiopia. The Borana of southern Ethiopia are experiencing many changes to their way of life, as documented by Solomon Desta in his paper on the transitions in

practices and livelihoods of the Borana as a result of the changing climate. Diversifying incomes, shifting to cultivation and investing in children's education are all strategies being used by the Borana to adapt under different conditions.

Climate change is also affecting forests in Ethiopia. Forests can provide a way for Ethiopia to help mitigate climate change. Zewdu Eshetu of the Ethiopian Forestry Research Center examines ways in which forests, if sustainably managed, can play a vital role in increasing societal adaptive capacity to climate change. Similarly, Alganesh Tesema of the Institute of Biodiversity Conservation highlights the importance of conserving agrobiodiversity to help respond to climate change. Agrobiodiversity plays a fundamental role in ecosystems, and its loss could mean fewer opportunities for the growth and innovation needed to boost agriculture at a time when new crop varieties and livestock breeds might be needed.

The livestock sub-sector will also be negatively affected by climate change. Getachew Gebru Tegegne describes how inputs such as feed, fodder and water will face impacts, and reviews adaptation practices such as changes in feed, manure and grazing management that can be adopted to mitigate the vulnerabilities within the sub-sector.

The focus shifts to policy in the last three papers of the proceedings. Selam Kidane Abebe of the Environmental Protection Authority (EPA) summarizes the relevant food security and climate change policies of Ethiopia and discusses the importance, gaps, outstanding issues and implementation constraints of these policies. Wondwossen Sintayehu, also of the EPA, discusses how climate change concerns are being mainstreamed into Ethiopia's agricultural and food security policies. The final paper is a contribution from Oxfam on research that was conducted in Ethiopia on gender gaps in the agricultural sector. The paper looks at gaps in access to extension, credit, information and other sources, and gaps in resource ownership that lead to disparity in crop productivity among men and women farmers. The paper concludes by providing recommendations for policy makers and other stakeholders to close these gaps and help women farmers achieve equal footing with men.

As Teklewold et al. points out in the first paper, climate change adaptation measures and policies should form the core of all development processes in Ethiopia and be implemented at the local level for maximum success. By presenting these collected papers, it is our hope that the recommendations provided can be taken up by policy makers at the federal, regional and local levels to help Ethiopia adapt to a changing climate and achieve its development goals.

References

- Byerlee D, Spielman DJ, Alemu, D, Gautam M. 2007. Policies to Promote Cereal Intensification in Ethiopia: A Review of Evidence and Experience. International Food Policy Research Institute. Development Strategy and Governance Division, Discussion Paper 00707.
- Conway D, Persechino A, Ardoin-Bardin S, Hamandawana H, Dieulin C, Mahe G. 2009. Rainfall and water resources variability in sub-Saharan Africa during the 20th century. *Journal of Hydrometeorology* 10: 41–59.
- Conway D, Schipper L. 2011. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change* 21: 227–237.
- [NMA] National Meteorological Agency. 2007. National Adaptation Program of Ethiopia (NAPA). Final draft report, NMA, Addis Ababa.
- Tarhule AA. 2005. Climate information for development: An integrated dissemination model. Presented at the 11th General Assembly of the Council for the Development of Social Science Research in Africa, 6–10 December 2005, Maputo, Mozambique. (Available from <http://www.codesria.org/IMG/pdf/tarhule.pdf>) (Accessed on 24 June 2014).
- Thornton PK, Jones PG, Ericksen PJ, Challinor AJ. 2011. Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. *Philosophical Transactions of the Royal Society* 369: 117–136.
- World Bank. 2007. Managing water resources to maximise sustainable growth: A country water resources assistance strategy for Ethiopia. Washington, DC: World Bank.
- World Bank. 2011. Ethiopia: Climate risk fact sheet. (Available from http://siteresources.worldbank.org/INTAFRICA/Resources/Ethiopia_Country_Note.pdf) (Accessed on 24 June 2013)

2. Impacts of climate change on crop production in Ethiopia

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Abstract

Agriculture is the foundation of Ethiopia's economy, accounting for 41% of gross domestic product (GDP), about 90% of exports and 81% of total employment. Many economic activities depend on agriculture, including marketing, processing, and export of agricultural products. Crop production constitutes more than 65% of the agricultural GDP. Climate change effects have been seen in Ethiopia over a long period of time through changes in the environment and natural resources and influences on livelihood activities and the national economy. Climate projections show continued warming but very mixed patterns of rainfall change. This paper assesses vulnerability and risks posed by climate change, evaluates best practices and technological adaptation strategies, and identifies knowledge gaps in managing risk and reducing vulnerability of crop production to climate change in Ethiopia.

Ethiopian farmers mainly depend on rainfed agriculture, which is highly vulnerable to climate change. Main climate hazards in Ethiopia are associated with rainfall variability, including amount, timing and intensity. The major effects of climate change on crop production include changes in regular crop planting times, length of growing season and shift in crop type or cultivars. Crop production in the country is highly correlated to the rainfall patterns. Rainfall variability and recurrent drought are leading to frequent crop failures, loss of life and property. Indigenous and improved technologies are used to reduce crop yield losses. Farmers use different management practices that include selecting the most favourable crops, cultivars, rotations, adjusting frequency of tillage, planting density, and timing of various operations, and applying intercropping, inter row cultivation techniques, traditional irrigation and water harvesting practices. Through research, different technologies have been developed, including crop varieties, agronomic, crop protection, soil and water conservation practices that are typically undertaken in response to drought. Whereas the negative impacts of climate change in Ethiopia are imminent and agricultural productivity and food security are already

precarious, it is important that climate change adaptation measures and policies should form the core of all the development processes and be implemented at the local level. This paper highlights the entry points in mainstreaming climate risks in the Ethiopian crop production to guide targeted research and development.

Keywords

Adaptation options; agricultural technologies; climate change; crop productivity; crop yield; Ethiopia; technology gaps.

2.1 Introduction

Agriculture contributes a remarkable proportion to the Ethiopian national economy, and the gross domestic product (GDP) is highly correlated to the performance of the agriculture sector. In recent years, a slight structural change from agriculture to the non-agriculture sector, specifically the service sector, has been observed (FDRE 2010). The contribution of agriculture to GDP declined from 57% to 41% between 1996 and 2010. Though its direct contribution is decreasing, agriculture is still important as it contributes to economic growth, supplies raw materials to the industrial sector as well as a market for industrial products. Agriculture also contributes nearly 90% to Ethiopia's export earnings.

Ethiopian agriculture is not highly productive but recent statistics indicate that the country is food self sufficient. The feeding habit of the population is heavily based on cereals. Whenever the rainfall varies slightly, the grain harvest and food availability suffers considerably. Production and productivity of the agriculture sector, specifically crop production, is constrained mainly because of poor land use, overgrazing, poor marketing structure, inadequate transport network and low use of agricultural inputs.

Ethiopia is extremely vulnerable to drought and other natural disasters such as floods, heavy rains, frost and heat waves (NMA 2007). Large parts of Ethiopia are dry sub-humid, semi-arid and arid. The country also has fragile highland ecosystems that are currently under stress due to population pressure and associated socio-economic problems. Ethiopia's history is associated, more often than not, with major natural and man-made disasters that have been affecting the population from time to time. Recurrent drought, famine and, recently, floods are the main problems that affect millions of people in the country. While the causes of most disasters are climate related, the deterioration of the natural environment due to uncontrolled human activity and poverty has further exacerbated the situation (NMA 2007). Ethiopia's farmers heavily depend on rain-fed agriculture, which is affected by the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC 2007) concluded that increased frequency of heat stress, droughts and floods negatively affect crop yields and livestock beyond the impacts of mean climate change.

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

Climate change, therefore, complicates efforts to increase food production and improve food security. More research and development funding is needed to better adapt food crops to climate change.

This paper highlights important climate change issues and its potential impact on Ethiopian agriculture, with a focus on crop production. Farmers' coping strategies and assessment of their effectiveness are also discussed.

2.2 Background and overview

2.2.1 Crop production in Ethiopia

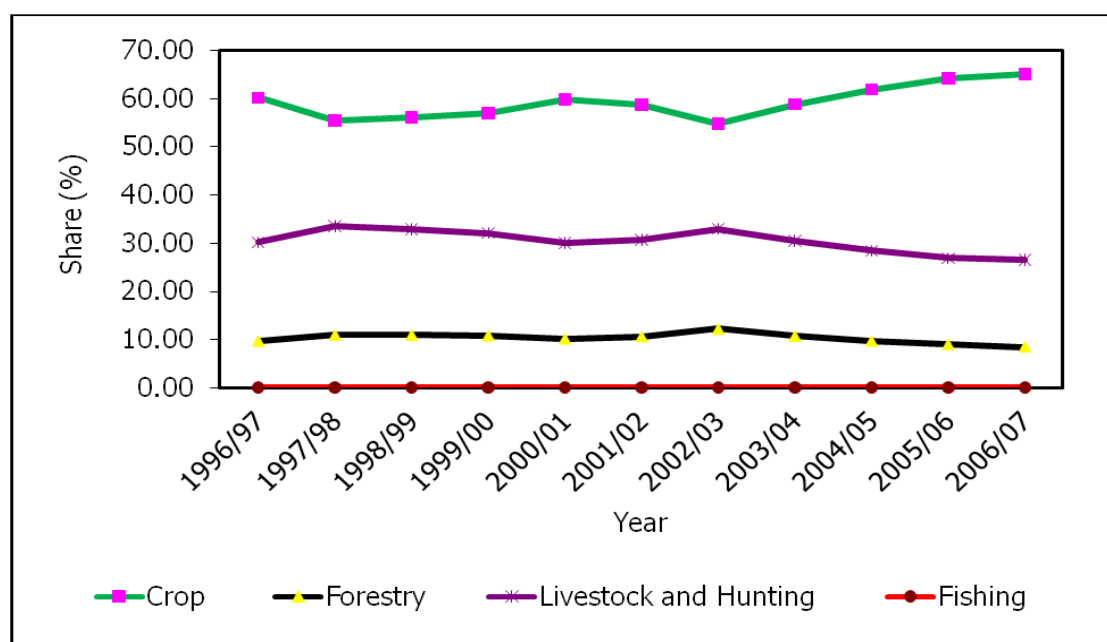
Ethiopia has 1.22 million square kilometres of landmass, with a diverse agro-ecology and a variety of climates, soil types, and water and genetic resources. About 73.6 million hectares (66% of the landmass) is potentially suitable for agricultural production (NMSA 2001). Of this, the arid, semi-arid and dry sub-humid areas of Ethiopia account for about 46% of the total potential arable land. Small-scale subsistence farmers dominate the crop production system in the country. These farmers account on average for 95% of the total area under crops and for more than 90% of the total agricultural output. Most of the food crops (94%) and coffee (98%) are produced by small-scale farmers, while the remaining 6% of food crops and 2% of coffee is produced by state and private commercial farms (Deressa 2006).

Crop production is estimated to contribute about 60 % of the total agricultural value. Since 2006/07 the share of crop agriculture from GDP exceeded 30% and its share from AGDP exceeded 65%. During the same period the shares of the livestock and hunting subsector and forestry were 12.3% and 3.9% from GDP and 26.5% and 8.4% from agricultural gross domestic product (AGDP), respectively (Figure 2.1). Though crop production is mainly subsistence, majority of the Ethiopian population (about 75%) depend on crop production for their livelihood.

Water development for the agricultural sector, especially irrigation, has not been adequately addressed despite the huge potential within the country. According to the recent data from Ministry of Water Resources, the total potential irrigable land of the country is estimated to be 3.7 million hectares. Of this, 2.9 million hectares are potentially irrigable with medium and large scale irrigation schemes. Currently, less than 5% of the total irrigable area is under

irrigated agriculture. The irrigated area varies from small to large size schemes with a variation across regions (unpublished CAADP Ethiopia study 2009).

Figure 2.1. Share of crop, livestock, forestry and fishery from the AGDP (percent)



Source: CAADP Ethiopia study 2009 (unpublished)

Crop production in the country is characterized by a very diverse range of production systems mainly related to the country's diverse agro-ecological conditions. Major cereal crops include teff, maize, sorghum, wheat, barley, millet, and oats; pulses include horse beans, field peas, lentils, chickpeas, haricot beans, and vetch; oil crops include sesame, noug, linseed, fenugreek, rapeseed, sunflower, castor bean, groundnuts, and safflower; and herbs and spices include pepper, garlic, ginger, and mustard. Coffee, tea, chat, and tobacco are the major cash crops. Major fruits include banana, orange, grape, papaya, lemon, mandarin, apple, pineapple, mango, and avocado. Other crops cultivated include sugar cane, fibres (cotton, sisal), vegetables (onion, tomato, carrot, and cabbage), roots and tubers (enset, potato, sweet potato, beets, yams, and cassava).

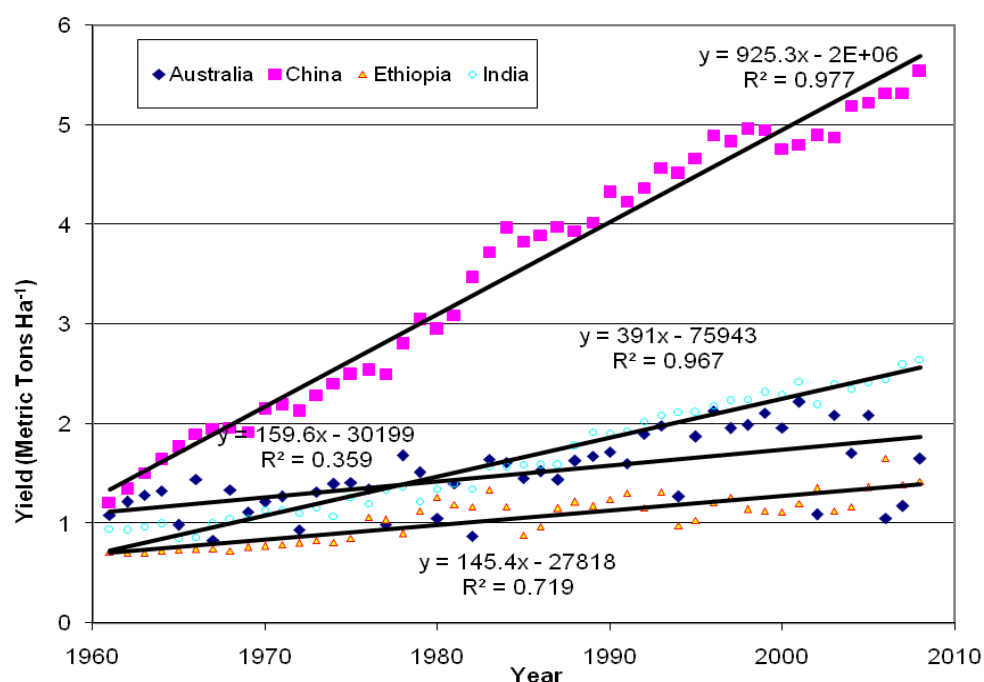
Table 2.1 presents production figures of major crops grown in Ethiopia. On average, more than 12 million hectares of land were planted during the period 2005–2010. About 71.3% of the area was allocated to cereals (teff, maize, barley, wheat and sorghum). Legumes accounted for 11.5% of the land allocated, while oil crops were allocated about 6%. The

average productivity of most crops has been steadily increasing (Figure 2.2), but is low as compared to many other countries. The equivalent of this in terms of production is 2.16 quintal/person/annum grain requirement. In Ethiopia, the per capita grain production as of 2007/ reached 2.13 quintal (unpublished CAADP Ethiopian Study2009).

Table 2.1. Area (ha), production (q) and productivity (q/ha) of major crops (2005-2010)

Crop	Parameter	2005/06	2006/07	2007/08	2008/9	2009/10
Cereals	Area	8,463,615	8,730,001	9,019,054	8,770,117	9,233,024
	Production	128,660,941	137,169,908	146,800,700	144,964,059	155,342,280
	Productivity	15.2	15.71	16.28	16.61	17.00
Pulses	Area	1,228,564	1,344,091	1,446,730	1,391,731	1,328,618
	Production	13,661,202	15,806,944	17,445,197	17,452,634	16,451,467
	Productivity	11.12	11.76	12.06	13.04	10.72
Oil crops	Area	740,922	707,059	875,855	855,147	780,915
	Production	4968294	5406849	7454594	6557044	6436144
	Productivity	6.71	7.65	8.51	8.96	9.81

Figure 2.2. Trends in cereal yields in Ethiopia, China, India and Australia (1960- 2008)



Source: FAO Statistical Database

The total area allocated to improved seeds in the 2009/10 cropping season was about 364,154 hectares. During the same season, maize and wheat accounted for the largest volume of improved seeds used, which amounted to about 5,720 and 4,690 tons respectively. According to CSA (2010), fertilizer was applied on 4.73 million ha of land which comprises of 39.4% of the total area cultivated in the same cropping season. About 826,564 tons of fertilizer was supplied in 2009, which is about 40% more than the amount imported in 2008.

Despite the potential of the country to grow diverse types of crops, a good harvest largely depends on good weather conditions, absence of pests and diseases, soil fertility conditions, and availability of draught animal power. Of significant importance in this regard are rainfall vagaries during any cropping season. These are very common in the semiarid areas, where climatic conditions are highly variable. According to EARO (2000), the major cause of underproduction is moisture deficit in the dryland areas of the country.

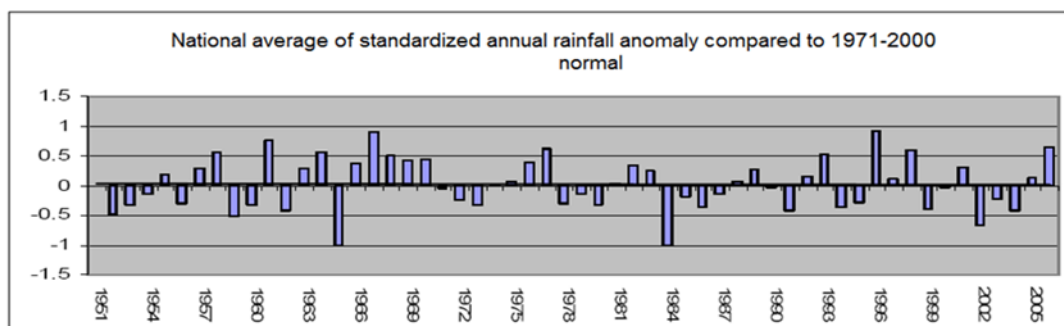
2.2.2 Climate change in Ethiopia

According to NMA (2007) the environment has become a key issue in Ethiopia in the last few decades. The main climate hazards in Ethiopia are associated with droughts and floods. The most prominent trend has been a tendency towards lower rainfall during the main growing seasons (March–May and December–February). A decline of 15% has been associated with anthropogenic Indian Ocean warming (Brown and Funk 2008). While floods have historically never been a major economic hazard in Ethiopia, in recent years there have been significant socio-economic disruption due to flooding, e.g. 1997 and 2006 (Tarhule 2005, Conway et al. 2009).

Climate change is something that is happening now in Ethiopia as illustrated in Figures 2.3, 2.4 and 2.5. The country has experienced both warm and cool years over the last 55 years. However, recent years have been the warmest compared to the earlier years (NMA 2007). Over the last decades, the temperature in Ethiopia increased at about 0.2° C per decade. The increase in minimum temperatures is more pronounced with roughly 0.4° C per decade (Brohan et al. 2006). Precipitation, on the other hand, remained fairly stable over the last 50 years when averaged over the country. However, the spatial and temporal variability of precipitation is high, thus large-scale trends do not necessarily reflect local conditions (Schneider et al. 2008; Conway et al. 2009). Years like 1952, 1959, 1965, 1972, 1973, 1978,

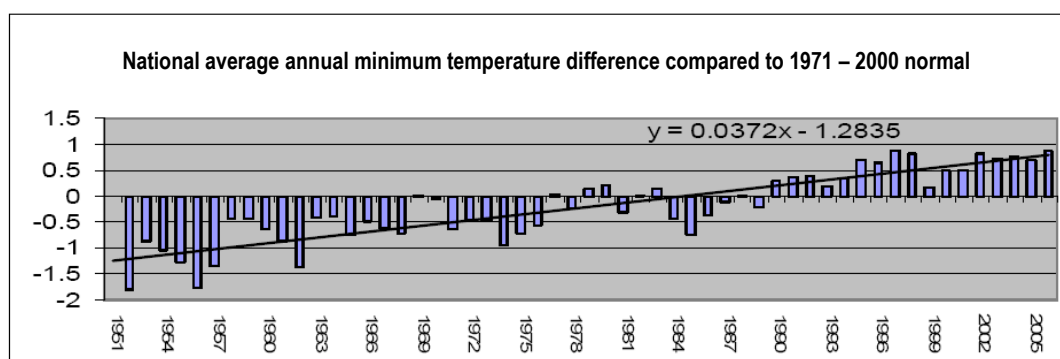
1984, 1991, 1994, 1999 and 2002 were dry while 1958, 1961, 1964, 1967, 1968, 1977, 1993, 1996, 1998 and 2006 were wet (NMA 2007). Studies by NMA have shown that there is a link between El Niño and La Niña phenomena and Ethiopian rainfall (NMA 2007).

Figure 2.3. Year to year variability of annual rainfall and trends in Ethiopia (expressed in normalized deviation)



Source: NMA 2007

Figure 2.4. Year to year variability of annual minimum temperature in Ethiopia (expressed in temperature difference)

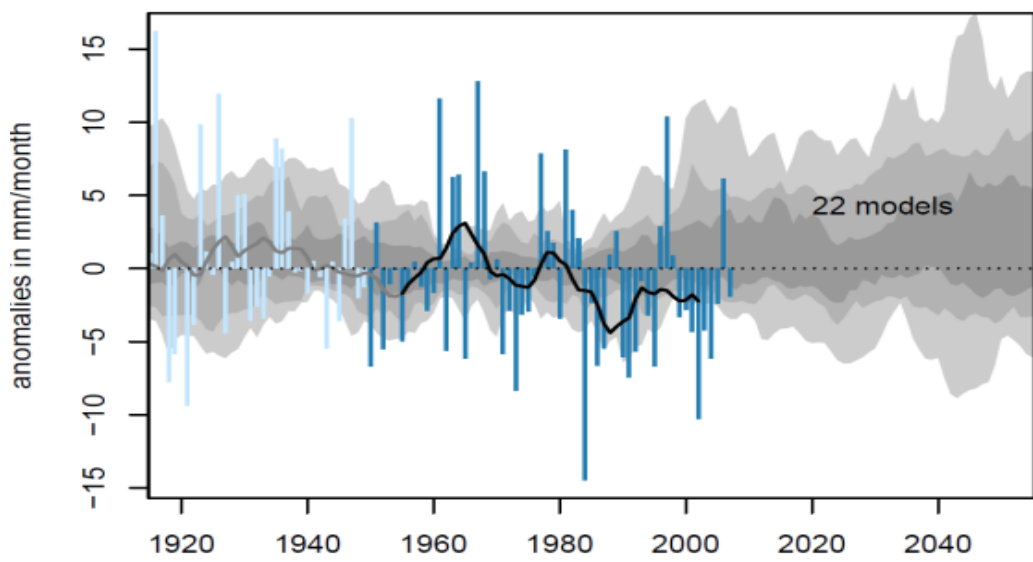


Source: NMA 2007

The future changes in precipitation and temperature as projected by various global climate models are also shown in Figure 2.5. Most of the global climate models project an increase in precipitation in both the dry and wet seasons. Studies with more detailed regional climate models, however, indicate that the expected precipitation change is uncertain (NMA 2008, Schneider et al. 2008). The temperature will very likely continue to increase for the next few decades with the rate of change as observed (NMA 2008, Brohan et al. 2006). The projected increases in the inter-annual variability of precipitation in combination with the warming will likely lead to increases in the occurrence of droughts. Furthermore, heavy rains and floods are

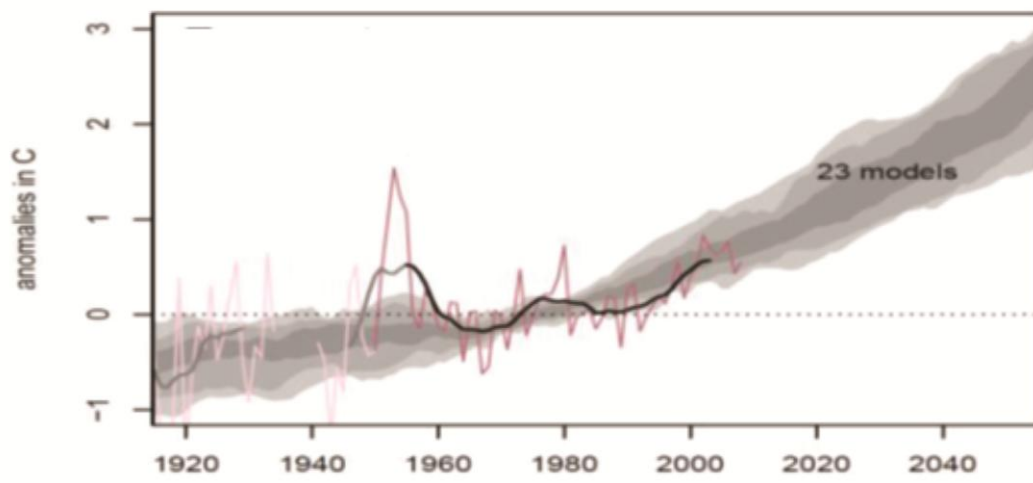
projected to increase as well (NMA 2008, Schneider et al. 2008, Brohan et al. 2006). Decreases in rainfall amount will be exacerbated by higher evaporation rates associated with increasing temperatures. Projections of temperature are more certain than those of precipitation, and considerable regional variations exist. Precipitation is expected to decrease in the northern regions, while southern areas could see an increase of as much as 20% (World Bank 2011).

Figure 2.5. Observed changes in precipitation in Ethiopia



Source: Brohan et al. 2006

Figure 2.6. Observed changes in temperature in Ethiopia

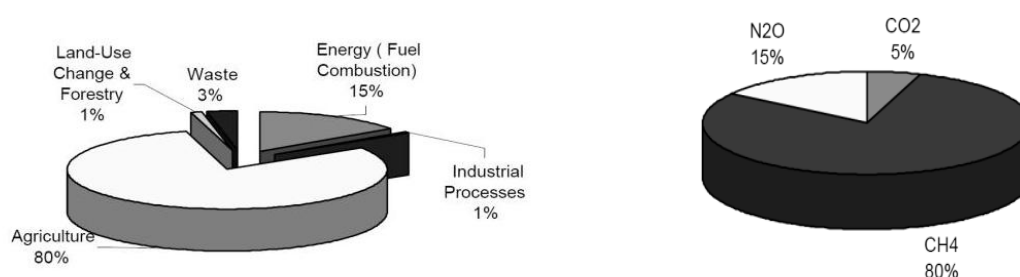


Source: Schneider et al. 2008

2.2.3 Ethiopia's contribution to climate change

Ethiopia's emission of greenhouse gases (GHG) in 1994 was estimated to be 900 kg CO₂ equivalent per capita per year. Compared to other countries (e.g. the U.S. emissions amount to 23.7 tonnes CO₂ equivalent per capita in 1994), Ethiopia's emissions are very low. Ethiopia's GHG emissions are mainly from agriculture, which contributes up to 80% of the total emissions (Figure 2.6). In addition to agriculture, the energy sector (heating, cooking, and transport) contributes 15% of the total emissions. Most of the energy consumption (95%) is from bio-mass sources, petroleum and electricity are of minor importance. Ethiopia's GHG emissions are closely linked to basic needs of the population: food production and heating. Methane constitutes 80% of the total emissions (Figure 2.6). Therefore, future GHG emissions will likely increase with the projected increases in population.

Figure 2.7. Total GHG emissions by sectors and the relative contribution of individual greenhouse gases to aggregated emission in 1994



Source: NMSA 2001

2.3 Biophysical responses of agro-ecosystems as related to crop production

Crop growth and development are simultaneously affected by numerous stress factors (Hansen et al. 2006, Porter and Semenov 2005). The changes in climate, water supply and soil moisture could make it less feasible to continue crop production in certain regions. Several factors directly connect climate change and crop productivity (Kurukulasuriya and Rosenthal 2003, IPCC 2007). These include i) average temperature increase, ii) change in rainfall amount and patterns, iii) rising atmospheric concentrations of CO₂, iv) pollution levels such as tropospheric ozone, and v) change in climatic variability and extreme events.

An increase in average temperature can have several effects. First, a temperature increase can lengthen the growing season in regions with a relatively cool spring and fall. It could also

adversely affect crops in regions where summer heat already limits production. Soil evaporation rates may increase, and the chances of severe droughts may also rise (Rosenzweig and Tubiello 1997, Sombroek and Gommers 1996). Warmer temperatures in high altitude areas may allow more insects to overwinter in these areas. Crop damage from plant diseases is likely to increase in temperate regions because many fungal and bacterial diseases have a greater potential to reach severe levels when temperatures are warmer or when precipitation increases (Rosenzweig and Hillel 1995). Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for growth and yields. Aggravated by rugged terrain and unwise land use, the predicted increase in precipitation and extreme weather events as manifested by floods will lead to severe land degradation in Ethiopia.

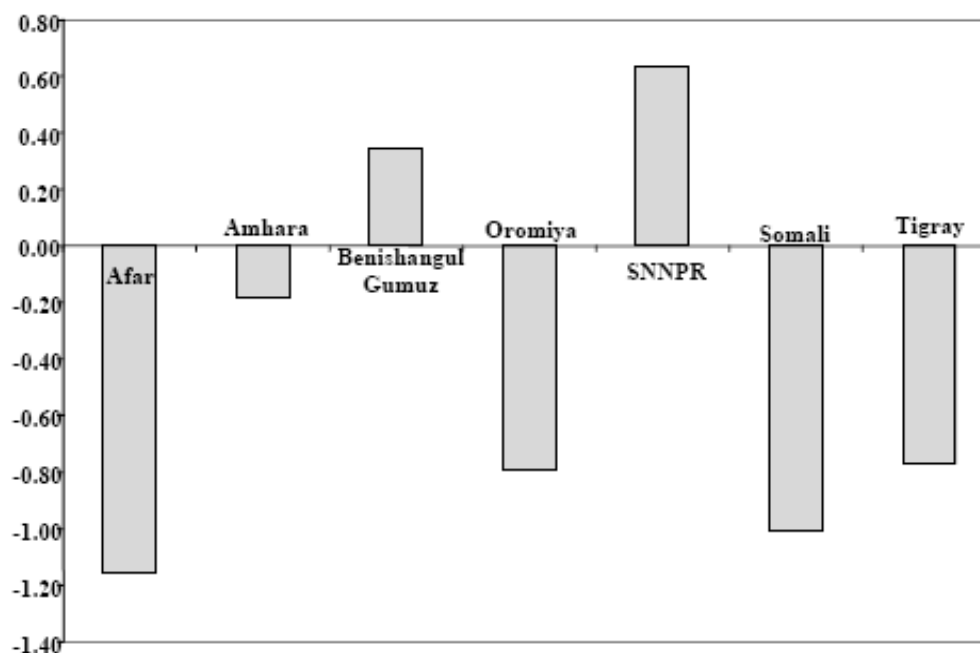
Increasing atmospheric CO₂ levels, driven by emissions from human activities, can act as a fertilizer and enhance the growth of some crops such as wheat, rice and soybeans. CO₂ can be one of the limiting factors that, when increased, can enhance crop growth. Other limiting factors include water and nutrient availability (Long 1991). While it is expected that CO₂ fertilization will have a positive impact on some crops, changes in temperature and precipitation may hinder any beneficial CO₂ fertilization effect (Kimball 1983,; IPCC 2007). The climatic changes that result from increased atmospheric CO₂ concentrations will undoubtedly influence the geographic range of insect and disease pests. An increase in atmospheric CO₂ is just as likely to increase the growth rate of weed species (Rosenzweig and Hillel 1995).

2.4 Effects of climate change on crop production

Crop production in Ethiopia is affected by failure of rains or occurrence of successive dry spells during the growing season. Food shortages resulting from adverse weather conditions are not new in Ethiopia. However, food shortages have increased in severity, with frequent shortages in recent years. Deressa et al. (2008) analyzed the vulnerability of Ethiopian farmers to climate change by generating vulnerability indices and comparing these indices across the seven regions of Ethiopia. The degree of vulnerability varies between the different regions (Figure 2.8) based on wealth, technology, availability of infrastructure and institutions, potential for irrigation, and literacy rate. In general, vulnerability to climate change in

Ethiopia is highly related to poverty. Integrated rural development initiatives aimed at reducing poverty can play a role in increasing adaptive capacity to climate change.

Figure 2.8. Vulnerability indices of the regional states of Ethiopia



Source: Deressa et al. 2008

2.4.1 Land preparation and other agronomic practices

Drought and delay in the onset of rain hamper regular land preparation operations and postpone optimal planting time. Drought also affects land preparation through either weakening or causing death of oxen that are a source of draught for tilling the land. Changes in rainfall patterns usually bring irregular rainfall distribution within the different crop phenology. Depending on the season, occurrence of rainfall during the harvesting time causes grain shattering, interference in harvesting operations, and pre-harvest seed germination. Crop loss has been reported in 1994, 1998, 2000, 2006 and 2008 (up to 100% losses) in part of West Arsi Zone of Oromia Region (FAO 1998, Feyissa 2009).

2.4.2 Planting times and growing season

Changes in climate are affecting harvests in dryland areas because of delays in onset and early cessation of rains that force farmers to miss the optimum planting time. As a result, farmers fail to plant long-season crops (Dryland Crops Research Strategy 2002). According to MoA and NRMRD (1998) due to low water holding capacity of the soil in the semi-arid areas, the

length of the two growing periods are generally short, ranging from 1-60 days (December-February season) and 60-120 days (March–May season) days. For instance the poor performance of rains during these seasons in April and May 2002 significantly affected planting and early growth development of the long cycle crops of maize and sorghum (DPPC 2003, Roach 2005).

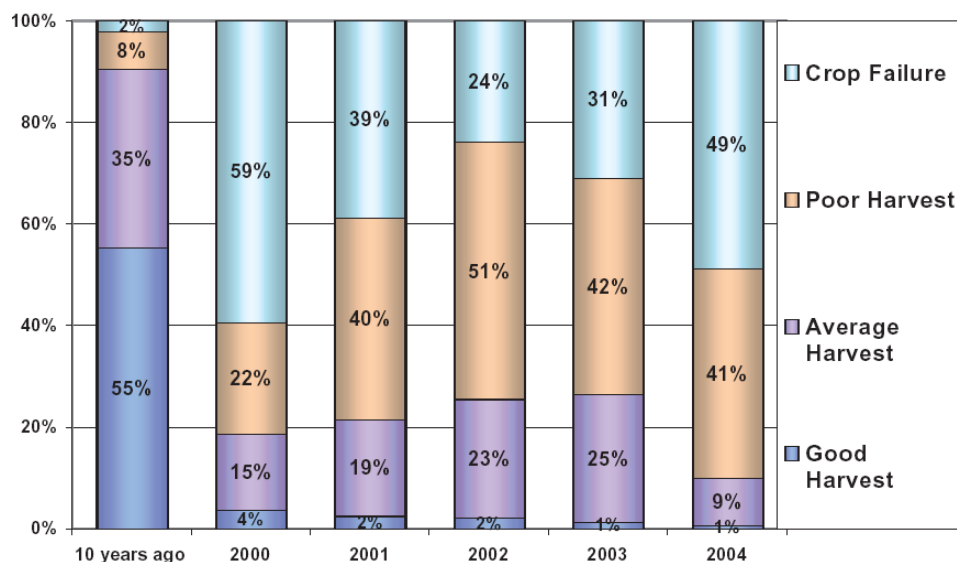
2.4.3 Change in crop type or varieties

Other examples of the impacts of climate variability include change in the opportunities to grow other crop types or varieties. According to ICRA (1996), crops like faba bean, lentil and wheat grown in the midlands are being replaced by sorghum, maize and haricot bean in response to declining and erratic rainfall distribution. In the Central Rift Valley, areas used for growing chick pea, peas and long maturing sorghum varieties are now growing medium or early maturing varieties of other crops (ICRA 1999). Replacement of maize and sorghum over time by teff owing to early maturity, late planting and lower total water consumption has been observed in most of the semi-arid regions. Giorgis et al. (2006) reported that currently maize and sorghum cultivars in Adama and Miesso areas are prone to the impact of water deficit. In both areas, the yield reduction percentage is higher as compared to maximum yield.

2.4.4 Crop yield

In Sub-Saharan Africa, rice, wheat and maize yield declines due to impacts of climate change are estimated to be 15%, 34%, and 10%, respectively (Nelson et al. 2009). The recurrence of rainfall shortages and their impacts has been observed to be frequent in some parts of the country. For example, reduction in crop production due to drought has been observed every year in Boricha and Metarobi areas in the southern part of Ethiopia since 2001. During the March to May season, maize yield losses of 80% in Boricha and 25% in Metarobi lowland area occurred in the year 2004 (Roach 2005). Similar findings were reported by Devereux (2006) who showed the high vulnerability of food production in semi-arid areas (Figure 2.9).

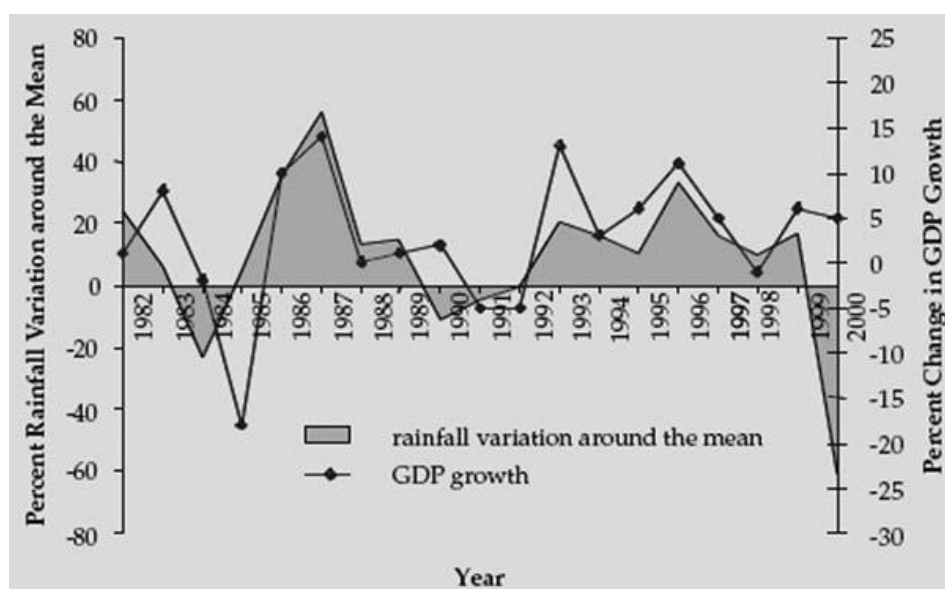
Figure 2.9. Perceived trends in harvests in Somalia Region, 1994-2004



Source: Devereux 2006

There is evidence that the food production trend in the country is correlated to the rainfall pattern (Deressa 2006, Grey and Soddoff 2005, Funk et al. 2003). Cycles of drought create poverty traps for many households, constantly thwarting efforts to build up assets and increase income. Figure 2.10 shows that during years of drought (1984/1985, 1994/1995, 2000/2001) are associated with very low GDP growth, whereas in years of good climate conditions (1982/83, 1990/91) the GDP growth is better.

Figure 2.10. Rainfall variability and GDP growth rates



Source: World Bank 2006

Water availability is the most critical factor for sustaining crop productivity in rainfed agriculture. Rainfall variability from season to season greatly affects soil water availability to crops, and thus poses crop production risks. Bewket (2009) observed an overall trend of higher rainfall to correlate with higher yield and lower yield variability in the Amhara region (Table 2.2).

Table 2.2. Correlation between cereal production and monthly, seasonal and annual rainfall in Amhara region

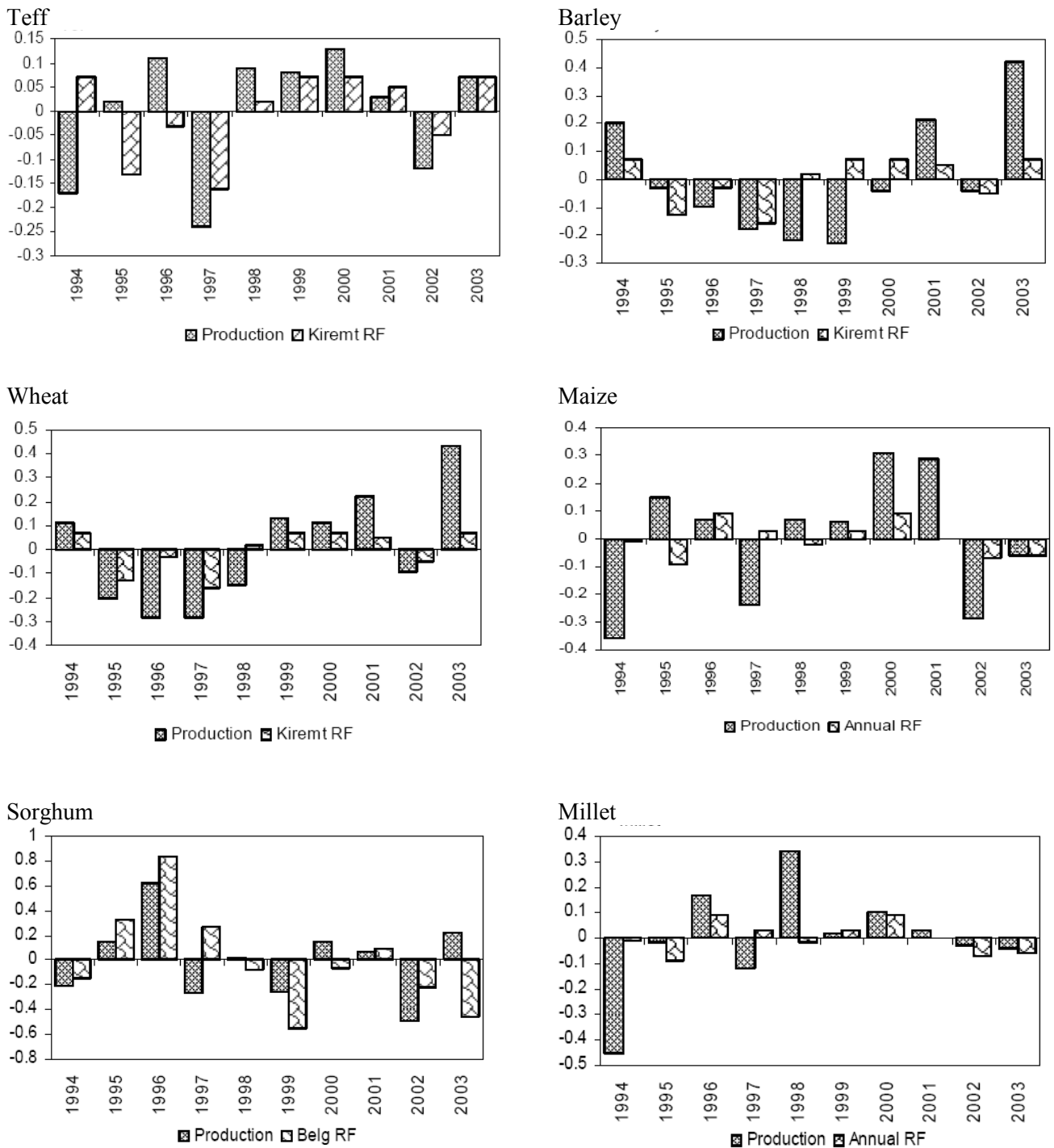
Months	Teff	Barley	Wheat	Maize	Sorghum	Millet
May	0.137	0.444	0.506*	0.309	0.492	0.503
June	0.189	0.421	0.414	0.188	0.503	0.176
July	0.199	0.049	0.612*	0.345	0.079	0.224
August	0.623*	0.273	0.564*	0.349	0.260	0.236
September	0.493	0.348	0.733**	0.149	0.212	0.127
Belg (short rain)	-0.001	-0.24	-0.17	0.19	0.57	0.21
Kiremt (long rain)	0.47	0.43	0.80***	0.23	0.10	-0.005
Annual	0.26	- 0.35	-0.17	0.33	0.37	0.23

*p < 0.1; ** p < 0.05, *** p < 0.01

Source: Bewket 2009

Rainfall variability is an important characteristic of climate in semi-arid regions that imposes crop production risks, especially on rainfed subsistence systems. Bewket (2009) showed that inter-annual and seasonal variability of rainfall is a major cause of fluctuations in production of cereals in Amhara region. As can be seen in Figure 2.11, the production of six cereal crops has shown negative anomalies in 1997 and 2002 due to high negative anomalies in seasonal rainfalls. In addition to these two years (1997 and 2002), the production of teff, maize, sorghum and millet recorded negative anomalies in 1994 as well, which contributed to the below-average total cereal production in the region (16% below the 10-yr mean). The year-to-year variability has been shown to be severe for sorghum, whose cultivation dominates the semi-arid and arid parts of the country which is prone to rainfall variability (Bewket 2009). Variability in seasonal rainfall, i.e. the accumulated amount of rainfall from the planting to the harvest of a crop, is higher in the areas with smaller amounts of rainfall.

Figure 2.11. Standardized anomalies of cereal production and seasonal and annual rainfall amounts in Amhara region (1994-2003)



Source: Bewket, 2009

Deressa et al. (2008) indicated that crop yield declined by 32.8% as a result of shocks such as drought, hailstorm, and flood. Conway and Shipper (2011) simulated the expected change in yield of four main crops (maize, teff, barley and sorghum) and found that higher rainfall produced modest effects on yield. Lower rainfall had greater impacts on yield for all the test

crops and produced more consistent reductions in yield in nearly all years. Yesuf et al. (2008) estimated that adopting adaptation measures to climate change can increase yield by about 95–300 kg/ ha.

2.5 Impact of climate change on food security

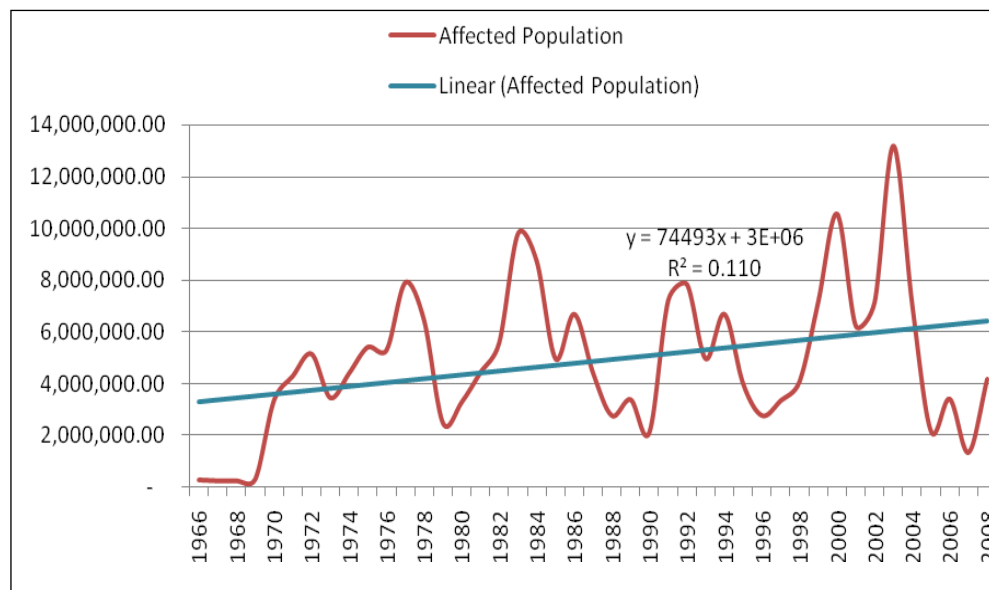
Variability in rainfall patterns and drought have disrupted crop production and exacerbated food insecurity in many parts of Ethiopia. Consequently, crop failure, water stress, crop disease and high food prices affect the population (Table 2.3 and Figure 2.12). The trends in number of food insecure people due to climate-related calamities is increasing, and reached its peak of 13 million in 2002/2003 (Table 2.3 and Figure 2.12). According to World Bank climate risk fact sheet of 2011, between 1999 and 2004 more than half of all households in Ethiopia experienced at least one major drought shock. These shocks are a major cause of transient poverty. Between 1900 and 2009, 47 major floods occurred, killing 1,957 people, affecting 2.2 million people, and costing the country about US\$16.5 million in damage (EM-DAT 2009).

Table 2.3. Effect of drought and rainfall variability on famine in Ethiopia

Drought	Regions affected	Impact on human life and property
1964-1966	Tigray and Wollo	About 1.5 million people affected
1973-1974	Tigray and Wollo	0.2 million people and 30% of livestock dead
1978-79	Southern Ethiopia	1.4 million
1982	Northern Ethiopia	2 million people affected
1983-1984	Ethiopia	8 million people affected
1987-1988	Ethiopia	7 million people affected
1990-1992	North, Eastern, Southeastern Ethiopia	About 0.5 million people affected
1993-94	Tigray and Wollo	7.6 million people affected
2000-2001	Ethiopia	About 10.5 million people affected
2002/2003	Ethiopia	13 million people in need of food assistance
2005-2006	Somali region	1.75 million people need food assistance
2007-2008	Arsi, West Arsi, and West Shoa	3.4 million people need emer. food relief
2009-2010	Eastern and Southern Tigray, Eastern Amhara, Eastern Oromia, Somali, SNNP, Gambella	5.2 million people required emergency food assistance

Source: Oxfam Ethiopia 2011

Figure 2.12. Trends in the number of food insecure people in Ethiopia (1966-2008)



Source: Oxfam Ethiopia (unpublished)

2.6 Economic impact of climate change

Climate change is likely to cost developing countries up to 19% of their GDP by 2030 (Nelson et al. 2009). Some studies (Asaminew 2009, Nelson et al. 2009, Deressa and Rashid 2009, Deressa et al. 2008, CEEPA 2006) carried out to determine the magnitude and direction of impacts of climate change on Ethiopian agriculture show that climate change poses a statistically significant impact on agricultural production. Using simulation models, Asaminew (2009) predicted the loss of US \$214 million of agricultural production as compared to the baseline scenario of no climate change of the 1990s. You and Ringer (2010) analyzed the potential challenges that climate change presents to Ethiopia's economy. Their findings indicate that the major impact of climate change on Ethiopia's economy will result from more frequent occurrences of extreme hydrologic events, which cause losses in the agricultural and non-agricultural sectors. If further irrigation development is not undertaken, the country will lose between US\$28 billion and US\$32 billion by the year 2050. This is about 40% of the GDP. The loss can be reduced to 35% if the water sector development plan is implemented.

Deressa and Rashid (2009) reported that increasing temperature during winter and summer reduces the net revenue per hectare by US\$997.85 and US\$1277.28, respectively. On the

other hand, increasing temperature during spring and fall increases net revenue by US\$375.83 and US\$1877.69, respectively (Table 2.4). According to this report, increasing the annual temperature reduces the net revenue per hectare by US\$21.61. Increasing precipitation during spring increases the net revenue per hectare by US\$225.08, whereas increasing precipitation during winter significantly reduces the net revenue by US\$464.76. Marginally increasing precipitation during summer and the fall also reduces the net revenue per hectare by US\$18.88 and US\$64.19, respectively, even though the level of reduction is not significant (CEEPA 2006, Deressa and Rashid 2009). High summer rainfall is associated with reduction of net revenue per hectare. Similarly, high rainfall during fall is associated with the reduction in net revenue per hectare due to the crops' reduced water requirement during the harvesting season. More precipitation damages crops and may re-initiate growth (CEEPA 2006).

Table 2.4. Marginal impacts of climate on net revenue per hectare (US\$)

Season	Winter	Spring	Summer	Fall
Temperature	-997**	338	-178*	1880**
Precipitation	-464**	225**	-18.9	-64

* Significant at 5% ** significant at 1%

Source: CEEPA 2006

Impact forecast projections carried out by Deressa and Rashid (2009) indicated that climate change will reduce the net revenue per hectare by 2050 and 2100 under three different climate models (CGM2, HaDCM3 and PCM). The result also indicated that the different AEZs affected differently by future changes in climate. This indicates that the level of damage due to climate change continues to increase and the availability of food will decrease in the future unless adaptation measures are undertaken (Table 2.5).

Table 2.5. Forecasted average revenue per hectare from SRES climate scenarios (US\$)

Impacts	CGM2		HADCM3		PCM	
	2050	2100	2050	2100	2050	2100
Change in net revenue/ hectare (US\$)	2182.6 (9.7%)	21830.6 (130.0%)	2728.8 (303.3%)	23601.2 (418.0%)	309.8 (15.4%)	21323.9 (103.4%)

Source: Deressa and Rashid 2009

2.7 Adaptation and mitigation strategies

Adaptation is a process through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effect of climate change by making the appropriate adjustment and changes (UNFCCC 2007). Farmers in Ethiopia have suffered from the impacts of climate change and variability. Messert (2009) reported that about 58% of the farmers in the Nile basin of Ethiopia implement some traditional adaptation measures indicating that they are aware of the changing climate. They practice changes in land use management (selection of crop types based on soil moisture and slope), choose the most favourable crops, cultivars, and rotations, adjusting frequency of tillage, planting density, timing of various operations, and applying intercropping and other technologies to increase efficiency of water use (ICRA 1999, 1997, 1996, Molla 2009). They have also introduced traditional irrigation and water harvesting schemes to cope with water stress during the growing period. Suggested adaptation strategies to improve crop production and productivity are summarized in Table 2.6, based on assessment studies of possible climate change scenarios with the corresponding crop challenge/impact.

Table 2.6. Farm level adaptation responses to climate change in crop production in Ethiopia

Climate change related scenario	Challenge/impact	Adaptation options
Regions known for crop production run out of the system due to lack of <250 mm seasonal rainfall	Crops water requirements cannot be met at any stage of growth and therefore crop production under rain-fed farming is impossible	Total irrigation Specialization
Irreversible shift in rainfall onset date from early to late	Planting window of long cycle cultivars narrowed High yielding long cycle maize cultivars can no longer be grown	Modifying growth cycle of cultivars befitting the modified rain season (medium or short duration cultivars)
Early season cessation	Shortened length of growing period, shortened grain filling period, shrivelled grain	Water harvesting for supplemental irrigation and increase water use efficiency, providing better condition for plants to grow Weather index based insurance scheme (the apex in climate risk management): important aspect of climate change adaptation

Climate change related scenario	Challenge/impact	Adaptation options
Soil water deficit, evaporative demand exceeds rainfall amounts	Crop production is possible, but rainfall insufficient to meet crop water requirement	Water harvesting for supplemental irrigation at critical growth stages Weather index based insurance scheme (partly, package) Increasing water productivity (grain yield mm-1) through cultivar choice and improved soil water management practices
Declining seasonal rainfall amount	Crops production is possible, but rainfall insufficient to meet crop water requirements	Water harvesting for supplemental irrigation during critical stages of growth Increasing water productivity through cultivar choice and improved soil water management practices
Shrink in size of belg rainfall areas	Production areas in which belg (short rain) and Meher (long rain) used to be merged with long cycle maize cultivars impossible	Shift to the short cycle maize cultivars
Unpredictable rainfall due to increased variability in rain onset date and extremes	Difficult to adopt fixed agronomic recommendations (date of sowing, cultivars, planting density and fertilizers)	Use seasonal rainfall forecast information from National Meteorology Agency for early warning and informed decisions Weather index based insurance scheme
Erratic distribution, extended dry spells (once the season sets in)	Reduced crop yield or total crop failure due to shortage of moisture at critical stages of growth	Modifying crop growth cycle to ensure that plants experience sufficient moisture during the critical stages Develop a suite of crop varieties (ranging from early to late maturing), so that the harvest is less vulnerable to stress at critical periods Diversify on-farm with other crops and enterprises Emphasize population breeding than pure line breeding
Torrential storms over a short time (days)	Rainfall exceeds infiltration capacity of the soil, reduced stand establishment, slow growth rate	Safe disposal of excess water (drainage), harvesting excess water to use during times of deficit
Heat load	Premature switchover from vegetative to reproductive stage (required heat unit met earlier than usual) Resurgence of new pests and pathogens	Shift the temperature optima for crop growth through breeding Varieties with roots that can withstand attack by soil-borne pests and diseases Develop heat tolerant cultivars

An illustrative list of technologies of adaptations that have been proved by a range of actors in Ethiopia is summarized in Tables 2.7 and 2.8. They include varieties, agronomic and crop protection practices and soil and water conservation practices, typically undertaken in response to drought and rainfall variability and proved to improve productivity by 117%.

Table 2.7. Improved varieties and production technologies for dry areas

Crop	No of technology	Days to maturity	Seed yield (t/ha)
Sorghum	19	60-134	2.5-5.0
Maize	7	85-125	2.5-5.5
Teff	9	70-120	1.2-2.8
Bean	21	74-120	2.0-3.2
Cowpea	5	65-90	1.6-2.0
Mung bean	3	70-80	1.4-2.0
Pigeon pea	2	110-130	1.0-1.5
Sesame	9	80-115	0.6-2.2
Groundnut	6	130-165	2.0-6.5

Source: Modified from Georgis et al. 2010

Table 2.8. Production techniques for improving maize productivity in dry areas

Management practices	Yield(t ha-1)
Broadcasting, no fertilizer, late weeding 6 weeks after emergence, flat planting (check, farmers practice)	1.3
Row planting, no fertilizer, late weeding 6 weeks after emergence, flat planting	1.7
No fertilizer, late weeding 6 weeks after emergence, tied ridges	1.9
No fertilizer, early weeding 3 weeks after planting, tied ridges	2.3
40 N 46 P ₂ O ₅ , early weeding 3 weeks after planting, tied ridges	2.9
Optimum planting date	Up to 50%
Spatial arrangement and plant population	Up to 20%
Field preparation and tillage practice	Up to 30%
Fertilizer	Up to 50%
Weed control	Up to 40%
Diseases and insect	Up to 30%

Source: Modified from Georgis et al. 2010

In Ethiopia, Molla (2009) and Yesuf et al. (2008) reported adoption of various yield related adaptation strategies to buffer impact of climate change on crop production. However the decision to employ adaptation measures is assumed to be a function of socio economic and technological factors (Table 2.9). Therefore, adaptation to climate change varies across

livelihood groups and geographical areas. According to Molla (2009), households with good access to formal agricultural extension, farmer-to-farmer extension, credit, and information about future climate change tend to apply adaptation measures on their farms in comparison with households with no access. Similarly, Yesuf et al. (2008) suggested that information about future climate change and access to formal and informal institutions tend to strongly govern each household's adaptation decisions. Shortage of land is one of the biggest constraints to adapting to climate change (Oxfam, unpublished). These results underscore the need to provide appropriate and timely information on future climate changes to farmers to alert and take appropriate actions.

Table 2.9. Constraints in implementing climatic change adaptation measures

Constraints	Percent contribution
Lack of information	43
Lack of funds	22
Labour shortage	16
Land shortage	11
Poor potential for irrigations	8
Total	100

Source: Molla 2009

2.8 Climate change related policy

Ethiopian farming is based on smallholder farmers and highly dependent on rainfed agriculture. Short-term fluctuations in weather patterns, therefore, have significant impacts on farm income. A loss of harvest could mean loss of life. Within the current economic and technological constraints, usually farmers barely adjust to short term climatic anomalies. In order to help households and the farming communities to better cope with climate variability and potential long-term climate changes, government policies must address stagnation and under-investment in the agriculture sector, the rapidly growing population and increase the ability of farmers to deal with shocks.

The Economic Development Policy of Ethiopia has given the highest priority to agriculture under the aegis of an agriculture-led industrial development. Agriculture is already built into the Agricultural Development Led Industrialization (ALDI) and the Growth and Transformation Plan (GTP) and is the foundation for many of the other activities (World

Bank 2008). In an effort to raise productivity of the agriculture sector and to be self-sufficient in food production, the government is focussing on generating and delivering technologies that will improve agricultural production.

Most of the policies, strategies and development plans do not explicitly reflect climate change, although many of the proposed activities are directly aimed at reducing the impacts of drought. However, many of these programmes and policies encourage higher agricultural productivity through intensification. The Early Warning and Response Department (EWRD) has been established with a new institutional mission under the MoARD. The EWRD has already developed a Disaster Risk Management Policy for Ethiopia that attempts to directly reduce the impact of disasters.

The availability of such policies and strategies is useful to develop the agriculture sector and improve disaster management. However, more effort is required in developing and strengthening of institutional capacity for mitigating the impacts of climate change. In this regard, intensifying investment in research and extension services to generate relevant technology and enhancing their immediate impact should be promoted. This should be linked with increased farmer access to appropriate technologies, climate information, measures to improve the marketing and distribution networks, and access to credit facilities.

While climate change will affect all sectors, it requires a coordinated approach among government institutions and NGO. Activities carried out by one ministry, agency or organization may contradict directly or indirectly with another and nullify one's effort unknowingly. Regular information exchanges and consultations would have to be organized between the weather forecasting stations, NARS, the agricultural extension service and farmer unions and associations. The NMA, Ministry of Agriculture, NGOs, and the NARS should effectively monitor current climate and environmental conditions in the country and establish an effective early warning system.

2.9 Knowledge and technology gaps

The knowledge and technology required for adaptation includes understanding the patterns of variability of current and projected climate, seasonal forecasts, hazard impact mitigation methods, land use planning, risk management, and resource management (FAO 2007). Taking

the above as a baseline, the following gaps are identified for a more focused and targeted research and development endeavour that can address the search for long-term solutions:

- Clear set of strategies to mainstream climate change in research and development programmes;
- Experience, facility and training on climate change;
- An alternative proven operational calendar to fit the delayed start, early cessation and occurrence of intra season dry spell needs to be developed;
- A range of early maturing varieties for different crops have been developed. Nevertheless varieties resistant to heat (hot-weather alert plans) and drought (based on water use efficiency) and with wider physiological elasticity should be released to adapt to changing growing conditions;
- Intensify cropping system research to altering cropping mix that are better suited to the changing climatic conditions;
- Suitable practices that use available rainwater more efficiently to mitigate impact of dry spells on crops and protect soil, which can improve inadequate soil fertility, soil water deficit (partly due to runoff losses coupled with high intensity rainfall), weak soil structure and slow water infiltration must be strengthened;
- Information that enables increased use of fertilizer and irrigation, supplementary and full season irrigation, to lessen impact of dry spells and drought;
- Approaches and strategies to integrate the use of climate forecasts into cropping decisions;
- Simulation to predict possible pest outbreak under different scenarios and develop controlling measures;
- The need for technology development to adapt to the impacts of observed medium- to long-term trends in climate, as well as to scenarios of climate change. This may include the increase of precipitation (wet-weather alert plan) and shift of amount precipitation between Belg and Meher seasons;
- Demonstrate and extend the available technology to the farming community;
- Information necessary in setting up crop insurance mechanism; and
- National seed reserve, specifically early maturing varieties for bad years.

2.10 Conclusions and recommendations

The threat of global warming and its consequence of changing weather patterns are already happening in Ethiopia. Ethiopia contributes so little to the cause of the problem and has the least capacity to deal with it. The negative impacts are imminent and agricultural productivity and food security are already precarious. Most evidence points to the fact that they will be exacerbated by climate change related events in future. The impact of the current climate variability on crop production has been clearly seen through its effects on crop planting times, length of growing season, shift in crop type or cultivars, production and productivity and economic loss. There is evidence that the food production trends in the country are highly correlated to the rainfall patterns, and as a result reduced crop yields and crop failures are frequent due to bad seasons.

The effects of climate change on agriculture in Ethiopia will depend not only on changing climate conditions, but also on the agricultural sector's ability to adapt through future changes in technology, changes in demand for food, and environmental conditions, such as water availability and soil quality. Management practices, the opportunity to switch management and crop selection from season to season and developing irrigation schemes and capacity can help the agriculture sector to cope with and adapt to climatic change. However, available improved technologies developed by the research system are based on previous experience on rainfall variability rather than forecasted or evidence based climate change scenarios in Ethiopia. The approaches are based only from a viewpoint of drought and specifically drought escape rather than encompassing the whole arena of climate change.

In order for agricultural production to meet the food demands of the ever-growing human population, the impact of the climate must be understood and integrated into any future planning. Lack of funds often hinders farmers from getting the necessary resources and technologies that can help them adapt to climate change. Thus, the agriculture lead industrialization policy, the agriculture and rural development policies and strategies and activities described in the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) and the Five Year Plan for Growth and Transformation (FYPGT) are vital to prepare for climate change in the long-term, but they will not necessarily be sufficient. Integrated rural development initiatives aimed at alleviating poverty can play the double role of reducing poverty and increasing adaptive capacity to climate change.

To improve crop productivity and production in the face of climate change in the future the following recommendations should be considered:

- Capitalize on the existing development policies and programmes and design action plans to implement short-term interventions/agricultural adaptation;
- Increase investments in agricultural productivity;
- Increase funding for adaptation programmes including accessing funds from international donors;
- Develop a strong network and partnership between different institutions to bring impact based on climate information;
- The government should give more attention to controlling population growth as an important part of its strategy to
 - reduce the impact of climate change on the social and economic wellbeing of the country. Unless new-borns are well fed and educated they will be liabilities rather than assets;
- Improve awareness and understanding of local communities about the relationship between climate change and crop production;
- Take inventories of community-based adaptation strategies and validate them for their sustainability and impact on poverty and inequality, and for the potential for replication or enhancement;
- Improve national and regional data collection, dissemination, and analysis to do detailed climatic analyses to define vulnerability and formulate decision support;
- Invest in community environmental and drought monitoring systems and improve community disaster risk reduction capacity;
- Improve and expand research to generate data and technologies appropriate to adaptation within the different agro-ecological zones. Uncertainty (lack of agreement) in future projections of rainfall although the projected increase in temperature is certain implies that climatic research has to be developed to address these knowledge gaps; and
- Invest in and improve agriculture extension services.

References

- Asaminew E. 2009. Climate Change: Ethiopia's Lost Millions. *New Path: African Forum for Intellectual Thought* 4: 1–5. (Available from <http://www.arrforum.org/publications/documents/New%20Path-%20June%202009.pdf>) (Accessed on 42 June 2013)
- Bewket W. 2009. Rainfall variability and crop production in Ethiopia: Case study in the Amhara region. In: Ege S, Aspen H, Teferra B, Shiferaw B, eds. *Proceedings of the 16th International Conference of Ethiopian Studies*. Trondheim, Norway. P. 823–836.
- Brohan P, Kennedy JJ, Harris I, Tett SFB, Jones PD. 2006. Uncertainty estimates in regional and global observed temperature changes: A new data set from 1850. *Journal of Geophysical Research Atmospheres* 111:D12106.
- Brown M, Funk CC. 2008. Food security under climate change. *Science* 319:580–581.
- [CEEPA] Center for Environmental Economics and Policy in Africa. 2006. *Climate Change and African Agriculture*. Policy Note No. 25.
- Conway D, Persechino A, Ardoin-Bardin S, Hamandawana H, Dieulin C, Mahe G. 2009. Rainfall and water resources variability in sub-Saharan Africa during the 20th century. *Journal of Hydrometeorology* 10: 41–59.
- Conway D, Schipper L. 2011. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change* 21: 227–237.
- [CSA] Central Statistical Authority of Ethiopia. 2000–2010. Annual Agricultural Sample Survey Report. Addis Ababa, Ethiopia.
- Deressa T, Rashid MH. 2009. Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures. *Journal of African Economies* 18: 529–554.
- Deressa T, Rashid MH, Ringler C. 2008. Measuring Ethiopian farmers' vulnerability to climate change across regional states. Discussion Paper 00806. International Food Policy Research Institute.
- Deressa T. 2006. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. CEEPA Discussion Paper No. 25, Centre for Environmental Economics and Policy in Africa, University of Pretoria.
- Devereux S. 2006. *Vulnerable Livelihoods in Somali Region, Ethiopia*. Institute of Development Studies Research Report 57.
- [DPPC] Disaster Prevention and Preparedness Commission. 2003. Update of emergency assistance requirements & implementation options for 2003. (Available from

- http://www.dppc.gov.et/downloadable/reports/appeal/2003/Appeal_2003_Update_%20August.pdf (Accessed on 24 June 2013)
- [EARO] Ethiopian Agricultural Research Organization. 2000. Dryland crops research strategy (DCRS). Addis Ababa, Ethiopia.
- EM-DAT. 2009. Emergency events database. Brussels, Belgium: Center for Research on the Epidemiology of Disasters, Université Catholique de Louvain. (Available from <http://www.emdat.be/>) (Accessed on 1 August 2011)
- FAO. 1998. Food supply situation and crop prospects in Sub-Saharan Africa. (Available from <http://www.fao.org/docrep/004/W8261E/w8261e00.htm>) (Accessed 17 May 2009)
- FAO. 2007. Climate change in agriculture, forestry and fisheries: Perspective, framework and priorities. (Available from <ftp://ftp.fao.org/docrep/fao/009/j9271e/j9271e.pdf>)
- FAO. 2009. *The state of food insecurity in the world 2009*. Rome, Italy.
- [FDRE] Federal Democratic Republic of Ethiopia. 2010. Growth and Transformation Plan (GTP) 2010/11–2014/15. Ministry of Finance and Economic Development (MoFED). Addis Ababa, Ethiopia.
- FEWS NET. 2005. 2005 Outlook for Pastoral Areas in the Horn of Africa, Washington D.C.
- Feyissa A. 2009. Climate Change Impact on Livelihood, Vulnerability and Coping Mechanisms: A Case Study of West-Arsi Zone, Ethiopia. MSc. Thesis Submitted to Lund University Masters Program in Environmental Studies and Sustainability Science (LUMES).
- Funk CC, Asfaw A, Steffen P, Senay G, Rowland J, Verdin J. 2003. Estimating Meher Crop Production Using Rainfall in the ‘Long Cycle’ Region of Ethiopia. Ethiopia Network on Food Security Monthly Report, May 20th, 2003 and FEWS NET/Ethiopia Emergency Alert of May 23, 2003.
- Georgis K, Dejene A, Malo M. 2010. *Agricultural based livelihoods systems in drylands in the context of climate change: Inventory of adaptation practices and technologies of Ethiopia*. Environment and Natural Resources Management Working Paper 38. Rome: Food and Agriculture Organization.
- Georgis K, Tadege A, Tibebe D. 2006. Estimating crop water use and simulating yield reduction for maize and sorghum in Adama and Mieso districts using the Cropwat model. Climate Change Impacts on and Adaptation of Agroecological Systems in Africa. CEEPA Discussion Paper No. 31, Special Series on Climate Change and Agriculture in Africa.
- Grey D, Saddoff C. 2005. Water for growth and development: a theme document for the 4th World Water Forum. Washington, DC: World Bank.
- Hansen JW, Challinor A, Ines A, Wheeler T, Moron V. 2006. Translating climate forecasts into agricultural terms: Advances and challenges. *Climate Research* 33: 27–41.

- [ICRA] International Center for Development Oriented Research in Agriculture. 1996. Supporting agricultural innovation in two districts of western Hararghe: the role of research, extension and farmers. Working document series 52. Wageningen, The Netherlands.
- [ICRA] International Center for Development Oriented Research in Agriculture. 1997. Strengthening farmer participatory in research and development in Jijiga zone: The case of moisture stress reduction in the plains and soil fertility management in the hills. Working document series 60. Wageningen, The Netherlands.
- [ICRA] International Center for Development Oriented Research in Agriculture. 1999. Livelihood and drought coping strategies on farm households in the central rift valley of Ethiopia: challenges for agricultural research. Working document series 76. Wageningen, The Netherlands.
- [IPCC] Intergovernmental Panel on Climate Change. 2007. Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. Cambridge: Cambridge University Press, .
- Kimball BA. 1983. Carbon dioxide and agricultural yield: an assemblage and analysis of 430 prior observations. *Agronomy Journal* 75: 779–786.
- Kurukulasuriya P, Rosenthal S. 2003. Climate change and agriculture: A review of impacts and adaptations. Climate Change Series Paper No. 91. Washington, DC: World Bank.
- Long SP. 1991. Modification of the response of photosynthetic productivity to rising temperature by atmospheric CO₂ concentrations: Has its importance been underestimated? *Plant, Cell & Environment*. 14: 729–739.
- [MoA and NRMRD] Ministry of Agriculture and Natural Resource Management and Regulatory Department. 1998. Agroecological zones of Ethiopia. Addis Ababa, Ethiopia
- Molla M. 2009. Climate change and crop agriculture in Nile basin of Ethiopia: Measuring impacts and adaptation options. A thesis submitted to the school of graduate studies of Addis Ababa University in the partial fulfillment of the requirements for the degree of Master of Science in economics under natural resource and environmental economics stream. Addis Ababa, Ethiopia.
- Nelson GC, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, Magalhaes M, Valmonte-Santos R, Ewing M, Lee D. 2009. Climate Change Impact on Agriculture and Costs of Adaptation. IFPRI Food policy report.
- [NMA] National Meteorological Agency. 2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. Report of the Federal Democratic Republic of

- Ethiopia, Ministry of Water Resources, and National Meteorological Agency. Addis Ababa, Ethiopia.
- [NMA] National Meteorological Agency. 2008. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. Report of the Federal Democratic Republic of Ethiopia, Ministry of Water Resources, National Meteorological Services Agency. Addis Ababa, Ethiopia.
- NMSA. 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). Addis Ababa, Ethiopia. (Available from <http://unfccc.int/resource/docs/natc/ethnc1.pdf>) (Accessed on 24 June 2013)
- Porter JR, Semenov MS. 2005. Crop responses to climatic variation. *Philosophical Transactions of the Royal Society* 360: 2021–2035.
- Roach R. 2005. Dried up, drowned out: Voices from the developing world on a changing climate. Middlesex, UK: Tear Fund.
- Rosenzweig C, Hillel D. 1995. Potential impacts of climate change on agriculture and food supply. US Global Change Research Information Office. (Available from <http://www.gcrio.org/CONSEQUENCES/summer95/agriculture.html>) (Accessed on 24 June 2013)
- Rosenzweig C, Tubiello FN. 1997. Impacts of global climate change on Mediterranean agriculture: Current methodologies and future directions: An introductory essay. *Mitigation and Adaptation Strategies for Global Change* 1: 219–232.
- Schneider U, Fuchs T, Meyer-Christoffer A, Rudolf B. 2008. Global precipitation products of the global precipitation center (GPCC). Deutscher Wetterdienst, Offenbach A. M., Germany.
- Sombroek WG, Gommers R. 1996. The climate change - agriculture conundrum. In: Bazzaz F, Sombroek W, eds. *Global climate change and agricultural production. Direct and indirect effects of changing hydrological, pedological and plant physiological processes..* Rome: FAO; New York: John Wiley & Sons. (Available from <http://www.fao.org/docrep/W5183E/w5183e0f.htm>) (Accessed on 24 June 2013)
- Tarhule AA. 2005. Climate information for development: an integrated dissemination model. Presented at the 11th General Assembly of the Council for the Development of Social Science Research in Africa, 6–10 December 2005, Maputo, Mozambique. (Available from <http://www.codesria.org/IMG/pdf/tarhule.pdf>) (Accessed on 24 June 2014).
- UNFCCC. 2007. Climate change: Impacts, vulnerabilities and adaptation in developing countries, assessment report.
- World Bank. 2007. Managing water resources to maximize sustainable growth: A country water resources assistance strategy for Ethiopia. Washington, DC: World Bank.

- World Bank. 2011. Ethiopia: Climate risk fact sheet. (Available from http://siteresources.worldbank.org/INTAFRICA/Resources/Ethiopia_Country_Note.pdf) (Accessed on 24 June 2013)
- Yesuf M, Di Falco S, Deressa T, Ringler C, and Kohlin G. 2008. The impact of climate change and adaptation on food production in low-income countries. Evidence from the Nile Basin, Ethiopia. IFPRI Research Brief15-11: International Food Policy Research Institute.
- You GJY, Ringler C. 2010. Hydro-economic modeling of climate change impacts in Ethiopia. IFPRI Discussion Paper 00960.

3. Trends in agricultural input use in Ethiopia: Implications for climate change adaptation and mitigation

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Abstract

Developing countries such as Ethiopia are facing two major challenges of meeting food requirements of their population and reducing greenhouse gas emissions. These challenges require significant adaptation and mitigation efforts. In Ethiopia, the government attaches great importance to use of chemical fertilizers and improved seed varieties to increase agricultural productivity. Despite government commitment, current grain production and productivity does not meet national food demands. Low productivity is attributed to various factors including limited use of technologies, land degradation and limited access to market and credit services by small-scale farmers. Use of chemical fertilizers and improved seeds has been growing at a slower pace than anticipated due to high prices, limited access to credit, weak extension services and distribution inefficiencies among other factors. Given the severity of food insecurity and high poverty level in Ethiopia, increasing agricultural productivity and production are key priorities to reduce and eliminate food deficits.

Although fertilizer use intensity is very low in Ethiopia, the negative impact of its increased use on climatic conditions should not be overlooked and measures that take into account ways of reducing its negative impacts are necessary. Similarly, promotion of high yielding crop varieties should take into account the role of landrace/biodiversity as a source of genetic material and its contribution to national food security. The government and all other actors in the agricultural sector should enhance conservation and utilization of landraces/biodiversity.

Keywords

Agricultural inputs; adaptation; mitigation; climate change.

3.1 Introduction

Agricultural development is considered a priority for stimulating growth, reducing poverty and enhancing food security in Ethiopia. The agricultural sector accounts for about 41% of GDP, and 90% of exports and 85% of employment (FDRE 2010). Performance of the agricultural sector, therefore, matters immensely for poverty reduction, food security and economic growth, both directly and indirectly. Agriculture is predominantly in the hands of small-scale subsistence farmers. As a result, the sector has remained fragmented and inefficient with a low output and low input system of production. The national average yield of major crops in 2009 was very low (about 1.69 ton/ha for cereals) (MoA 2010).

The government's overall development strategy emphasizes increased and efficient use of productivity enhancing inputs such as fertilizers and improved seeds. In addition, the government has developed policies to support the agricultural sector. The consumption of agricultural inputs has increased over the past eight years but there is still room for improvement. In Ethiopia, the most commonly used yield enhancing agricultural inputs by smallholder farmers are chemical fertilizers and improved crop seed varieties.

This paper analyses the trends in the consumption of these inputs and identifies key points for developing adaptation and mitigation strategies.

3.2 Trends in agricultural inputs use

3.2.1 Trends of chemical fertilizer use

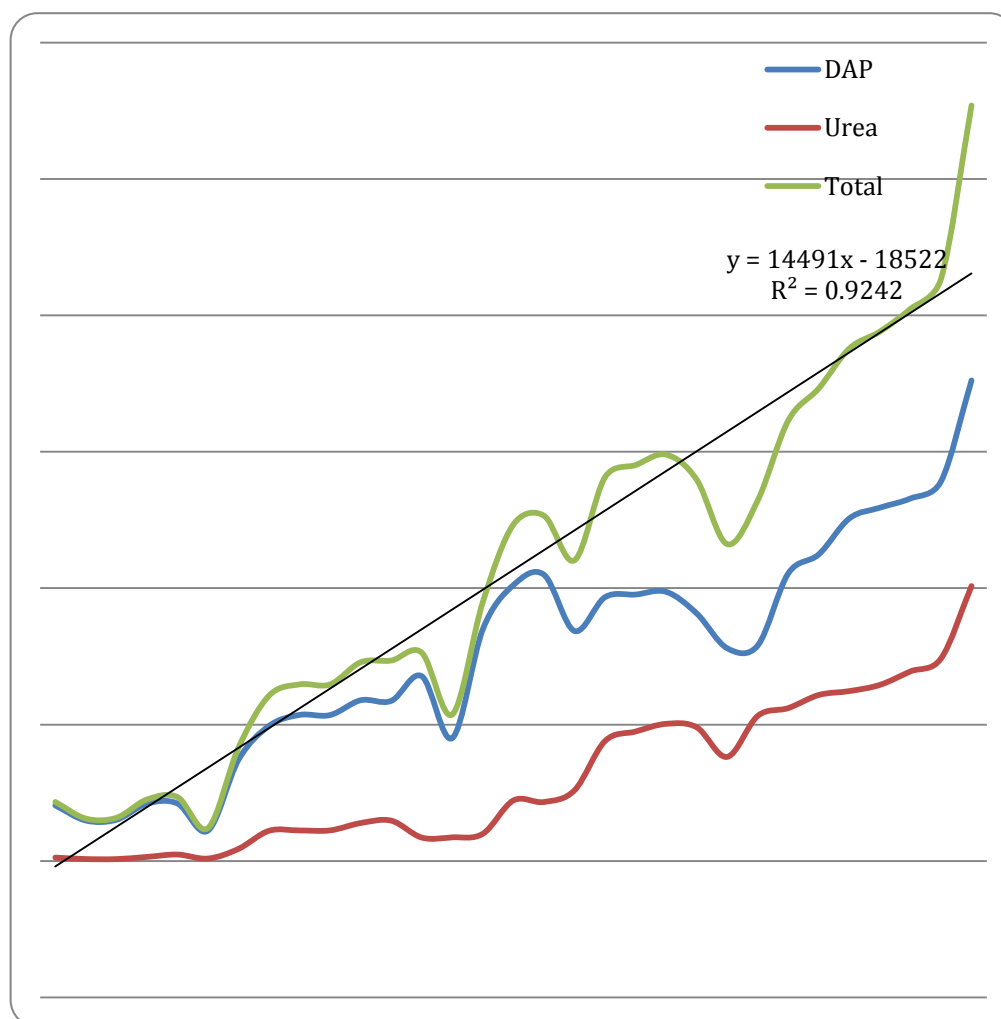
In Ethiopia, traditional land fallowing and crop rotation practices used to maintain soil fertility have been gradually reduced due to high population pressure and limited availability of cultivable land. The use of manure to add organic materials to the soil is also hampered by the increased use of farm yard manure and crop residues as a source of energy (Setotaw et al. 2000). Thus, in order to restore nutrients to the depleted soils, provision of chemical fertilizer to farmers has been one of the major activities of the extension programmes in Ethiopia.

Inorganic fertilizers were first introduced to Ethiopia following three years (1967–69) of simple fertilizer demonstration carried out by the government with the assistance of the Food and Agriculture Organization's (FAO) Freedom from Hunger Campaign. Since then the most

common types of inorganic fertilizers that have been imported and used in Ethiopia are Diammonium Phosphate (DAP) and Urea.

In spite of the prevalence of a number of utilization and marketing related problems, chemical fertilizer consumption has shown considerable growth over the last four decades. Starting with an average annual consumption of less than 1,000 metric tons (MT) during 1967–1971, fertilizer consumption increased to about 146,000 MT in 1990, to 298,000 MT in 2000 and reached a record high of about 554,000 MT in 2010. In the past 10 years, the average annual growth rate in fertilizer use is about 7.4% (Figure 3.1 and Annex 3.1). Of the total chemical fertilizer used in the country, about 65% is DAP while 35% is Urea (Techane 2002, FDRE 2010).

Figure 3.1. Fertilizer consumption trends in Ethiopia



Source: Ministry of Agriculture annual reports

Although the total consumption of chemical fertilizers has shown an increasing trend, uptake amongst farmers in Ethiopia has been very low due to various institutional, economic and physical factors. For instance, in the 1999/2000 production season the average fertilizer consumption was about 35 kg per hectare for major crops. Fertilizer use per hectare increased to about 49 kg in 2009/10. This shows that the level of fertilizer application is too little to support a sustainable yield increase. Hence, the major challenge facing the country is how to increase fertilizer use necessary to attain a sustainable increase in yield.

More than 90% of all fertilizer used in Ethiopia is by smallholder farmers and the remaining 10% is by private commercial farms, state farms and research centres. Four regions alone (Oromia, Amhara, SNNPRS and Tigray) account for more than 90% of the total fertilizer consumed in the country. Three cereals namely, teff, maize and wheat normally get top priority in fertilizer use by smallholder farmers. In 2009/10, the combined share of these crops was 92% in the four high fertilizer consuming regions (DSA 2010). Estimates have shown that there is a wide gap between current amount of fertilizer use and the estimated potential demand. Rough estimates of potential demand for chemical fertilizer in Ethiopia can reach as much as 3 million metric tons per year. The main reasons for low consumption of chemical fertilizers are lack of adequate extension services and limited access to markets and credit services by smallholder farmers.

Results of a survey conducted by the Development Studies Associates in 2010 and other studies undertaken by different individuals in different times (Bezabih 2000, Croppenstedt et al. 1999, Lelissa 1998, Teressa 1997, Techane 2002) have shown that factors such as farmer's access to capital such as credit and extension services, use of hired labour, household size, area under improved seed and level of education have a significant positive impact on the probability of adoption of chemical fertilizer and intensity of its use. These studies also show that farmers are price sensitive and a temporary price subsidy for urea may be useful to help address the nutrient imbalance currently observed in Ethiopia.

Key issues in the fertilizer sub-sector

Although consumption of chemical fertilizers in Ethiopia has shown some increase over the last ten years, majority of crop farmers still apply far less than the optimal amount. One of the key issues in the fertilizer sub sector is that the majority of farmers are not using location specific fertilizer recommendation rates. Hence, there is an urgent need to speed up the on-

going efforts of generating recommendations based on soil characteristics and enhancing the capacity of development agents to properly advise farmers on the correct use of fertilizers. In addition, different alternatives to DAP and Urea should be considered in line with different agro-ecological zones, soils and crop types.

Many researchers in Ethiopia recommend the use of a combination of inorganic and organic fertilizers for maintaining soil fertility. This combination often results in improved efficiency of nutrient and water use, reduces dependency on the imported fertilizers and reduces cost of enhancing soil fertility. Currently there are some initiatives in Ethiopia to produce chemical fertilizers domestically. Other government efforts include formulation of policies with the aim of creating a competitive fertilizer marketing system, liberalization of the fertilizer market, elimination of fertilizer subsidy, deregulation of fertilizer prices and announcement of fertilizer manufacturing and trade law. Nevertheless, some drawbacks have been observed in meeting these policy objectives as the response from the private sector is limited. Other challenges include lack of business experience, trained personnel and finance by the cooperative societies involved in marketing and distribution of the fertilizers.

3.2.2 Trends of improved seed use

Extension and demonstration packages undertaken by the Ministry of Agriculture (MoA) and NGOs have demonstrated that grain yields of major cereal crops can be easily tripled with the use of fertilizers and improved seeds. However, it is estimated that less than 3% of the cultivated area is planted with high yield variety (HYV) seeds. The Ethiopian National Agricultural Research System (NARS) has developed and released a number of improved varieties of various crops, many of which are currently in use. However, an overwhelming majority of farmers even in areas with adequate and reliable rainfall still rely on traditional varieties.

The use of improved seeds has shown an increasing trend from 2001 to 2010 with an average annual growth rate of 19%. Available data indicate that improved seed consumption increased from about 20,000 tons in 2001 to about 59,000 tons in 2010 (Annex 3.2). Seed production and consumption, however, is mainly limited to cereal crops namely, wheat, maize, barley and teff. Public seed producers and suppliers have more than 90% share in the distribution of certified seeds while the remaining 9% share is by private seed growers and suppliers.

Although use of improved seeds has shown an increasing trend, it is by far below the seed demand (Belay and Adugna 2006). Potential annual demand for grain seeds in Ethiopia is estimated in the range of 400,000–500,000 tons (Belay and Adugna 2006). On the contrary, the country's average actual annual improved seed consumption is about 22,000 tons. This indicates that there is a strong challenge facing policy makers, researchers and extension personnel to convert the potential demand into effective demand as farmers are currently using only about 5% of the potential demand for improved seeds.

The current seed supply system of Ethiopia is coordinated and facilitated by the federal and regional governments implying the existence of a weak marketing system. The system starts from demand estimation followed by an assessment of the available supply potential by the MoA. The MoA identifies gaps and designs strategies to fill these gaps in collaboration with the regional agricultural bureaus, the Ethiopian Institute of Agricultural Research (EIAR) and seed growers. The outcome of this process is discussed and finalized in a national meeting involving all stakeholders. The regional governments generate annual seed demand estimates, facilitate credit availability, coordinate seed multiplication on farmers' fields and link cooperatives with seed suppliers among other things.

Key issues in the seed subsector

The demand for improved seeds is not met (especially for hybrid maize) due to the following main reasons:

1. Inconsistent and inaccurate estimation of farmers' demand for seed

Inconsistent and inaccurate estimation of farmers' demand for seed has led to both over and under estimation on the quantity of seed supplied. Under estimation leads to reduced supply of improved seed while over estimation leads to increased carry over stock and hence high seed carrying cost. Estimation of demand should, therefore, be based on reliable information obtained from farmers, seed distributors and researchers. Thorough analysis of past consumption trends and factors affecting use of improved seeds by farmers is also important.

2. Productivity gaps and financial constraints in contract grower schemes

Productivity gaps and financial constraints in contract grower schemes have resulted in reduced quantity and quality of seed produced. Retrieval rate from contract growers is often very low due to poor production techniques as well as low financial incentives. Despite the fact that EIAR has developed several improved varieties of different crops and these varieties have undergone field trials before their release, there is limited capacity for the production and supply of breeder seeds or parental seeds of these released varieties. This in turn has created a formidable challenge in the production of basic or foundation seeds and subsequent production and supply of certified seeds by the public and private seed companies.

3. Lack of coordination between production, processing and delivery

There is lack of coordination between production, processing and delivery of improved seeds. One of the reasons is that the current cleaning, testing and storage facilities are not aligned to major seed producing areas. This has resulted in the increasing logistics cost and slow delivery in remote areas. The existing seed distribution model is not competitive in providing choices to farmers as the bulk of seed is mainly channelled through cooperative societies and public entities. Although the country's seed policy allows increased participation of the private seed producers and distributors, the response from the private sector has been limited due to various factors including limited access to basic seeds, land, credit facility and government intervention in all commercial aspects of the seed system.

3.3 Implications on climate and mitigation strategies

3.3.1 Chemical fertilizers

Chemical fertilizers play a key role in increasing crop productivity thus contributing towards efforts made by the government of Ethiopia to achieve food security. While chemical fertilizers have these important roles, there are also several harmful effects. Overuse of chemical fertilizers is a significant source of greenhouse gas emissions and contributes greatly to climate change. Chemical fertilizers may pollute waterways and the air, soil acidification and mineral depletion of the soil.

Feeding the plants indirectly, by means of organic fertilizers, enhances the chemical, physical, and biological health of the soil. In this respect, plant based composts are recommended from

an environmental point of view. However, it is very difficult to solely depend on composts in the face of the immediate need for increasing food production and limited capacity of smallholder farmers to produce, transport and apply compost on their scattered small plots. Although the intensity of chemical fertilizer use is very low (about 49 kg per hectare of land under major crops in 2009/10) in Ethiopia, well planned actions are required to minimize its negative impact on the environment.

3.3.2 Improved seed varieties

The government of Ethiopia has been pursuing strategies aimed at increasing agricultural productivity in order to accelerate economic growth, achieve food security and improve the wellbeing of its people. Improved seed has been recognized as a core component to realizing this strategy.

Compared to other agricultural inputs, improved seed has been shown to have the greatest potential to increase farm productivity. Improved seed thus plays a pivotal role in increasing agricultural productivity. However, efforts in promoting improved seeds should take into account the role of landraces as improved seeds may lack traits found in landraces given the changing climate conditions. Landraces/biodiversity must be recognized as the foundation of economic productivity and sustainable development. Hence, on-going efforts aimed at promoting the use of improved seeds should also give due consideration to the identification and implementation of ways and means of continuous maintenance and use of landraces by smallholder farmers.

3.4 Conclusions and recommendations

The major challenges confronting Ethiopia are improving rural and urban food security and stimulating underlying food system development. There is growing concern that it is becoming increasingly difficult to achieve and sustain the needed increase in agricultural production based on expansion of cultivated area. This is because of limited opportunities for expansion especially in the densely populated highlands of the country. Despite strong government commitment to increase agricultural production, current grain production and productivity does not meet the food requirements of the population. The main reasons for low level of agricultural productivity are limited use of improved yield enhancing technologies, land degradation and limited access to market and credit services by small-scale farmers. The

use of chemical fertilizers and improved seeds has been growing at a slower pace than anticipated. The slow growth rate in use of chemical fertilizers and improved seed has largely been due to supply irregularities, high prices, limited access to credit, weak extension services and distribution inefficiencies.

Projections show that the population will continue to grow at a faster rate and hence contribute immensely to the severity of food insecurity and poverty. Agricultural productivity has to increase in particular if food deficit problems are to be reduced and finally eliminated. Hence, the solution to food insecurity will depend on measures aimed at increasing yields which in turn is determined by sustainable growth in the use of yield enhancing technologies, such as chemical fertilizers and improved seed varieties along with improved management and use of natural resources. Ethiopia's agricultural sector is no exception in the global environment. As agriculture is both a victim of and contributor to climate change there is a need to find ways of mitigating its contribution to global warming through greenhouse gas emissions and minimizing the impact of climate change on agriculture.

References

- Belay S, Adugna T. 2006. Program for Africa's Seed Systems (PASS) Country report: Ethiopia.
- Bezabih E. 2000. The role of new varieties and chemical fertilizer under risk: The case of smallholders in Eastern Oromia, Ethiopia. Ph.D. dissertation, University of Hannover, Shaker Verlag, Germany.
- Croppenstedt A, Demeke M, Meshi M. 1999. An empirical analysis of demand for fertilizer in Ethiopia. *Ethiopia Journal of Agricultural Economics* 3: 1–27.
- [DSA] Development Studies Associates. 2010. "Draft report on the impact evaluation of fertilizer usage".
- [FDRE] Federal Democratic Republic of Ethiopia. 2010. Growth and Transformation Plan Volume 1.
- Lelissa CA. 1998. Determinants of adoption, intensity and profitability of fertilizer use: the case of Ejere District, West Showa. M.Sc. Thesis. Addis Ababa University, Ethiopia.
- [MoA] Ministry of Agriculture. Annual reports of the Ministry of Agriculture.
- Setotaw F, Verkuijl H, Tannger DG, Gebre T. 2000. Optimising fertilizer use in Ethiopia: Results of a baseline survey of fertilizer adaption in Arsi Zone. Sasakawa-Global 2000, Addis Ababa.
- Techane A. 2002. Determinants of fertilizer adoption in Ethiopia: The case of major cereal producing areas. M.Sc. Thesis. Alemaya University, Ethiopia.
- Teressa A. 1997. Factors influencing the adoption and intensity of use of fertilizer: The case of Lume district, central Ethiopia. *Quarterly Journal of International Agriculture* 36: 173–187.

Annex 3.1. Trends in chemical fertilizer use in Ethiopia (in metric tons)

Year	DAP	Urea	Total
1980	40,742	25,45	43,287
1981	29,668	1,444	31,112
1982	30,255	1,418	31,673
1983	42,047	3,008	45,055
1984	42,147	4,737	46,884
1985	22,296	1,823	24,119
1986	74,345	8,918	83,263
1987	99,076	22,196	121,272
1988	107,108	22,404	129,512
1989	107,011	22,460	129,471
1990	117,866	27,843	145,709
1991	117,392	29,573	146,965
1992	135,467	17,191	152,658
1993	90,109	17,348	107,457
1994	170,000	20,000	190,000
1995	202,312	44,410	246,722
1996	209,883	43,269	253,152
1997	168,623	51,808	220,431
1998	193,395	87,976	281,371
1999	195,345	94,919	290,264
2000	197,345	100,562	297,907
2001	181,545	98,057	279,602
2002	155,941	76,329	23,2270
2003	157,955	106,394	264,349
2004	210,837	112,105	322,942
2005	224,819	121,735	346,554
2006	251,156	124,561	375,717
2007	259,020	129,121	388,141
2008	265,768	138,988	404,756
2009	278,239	148,437	426,676
2010	352,309	201,576	553,885

Source: Ministry of Agriculture annual reports

Annex 3.2. Trends in improved seed use in Ethiopia

Year	Use (in metric Tons)
2001	20,151
2002	9,194
2003	12,025
2004	14,949
2005	15,343
2006	22,531
2007	20,568
2008	24,605
2009	27,692
2010	58,891

Source: Ministry of Agriculture annual reports

4. Water management practices to enhance food production in Ethiopia

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Abstract

Water shortage is already a problem in many parts of Ethiopia, particularly in the arid and semi-arid areas. Human induced changes in land use and low levels of water management have accelerated desertification processes. This situation is unlikely to be reduced and may be exacerbated by climate change as precipitation is projected to decrease, while temperature and evaporation will increase. Consecutive droughts have led to chronic water scarcity across many parts of the country, leading to acute water shortages. This means that areas dependent on rainfall are getting exposed to water shortages in years where the seasonal rainfalls perform poorly and fail to recharge rivers, groundwater and soil moisture. In addition, water resources in Ethiopia are becoming limited and land holding is becoming fragmented due to increasing population. The traditional practices of increasing area under cultivation cannot be considered as an option to address current climate change. To deal with the problem, large and small-scale irrigation, rainwater harvesting, and water efficient technologies are considered in the National Adaptation Program of Action (NAPA) of Ethiopia. This demands investment to expand and upgrade the existing irrigation schemes, small rainwater storage structures and equally important to upgrade rainfed agriculture to produce more crops with less water. Using the drip irrigation method, for example, 33% of irrigation water can be saved, and if irrigation canals are lined, 10–15% of irrigation water can be saved. Human resource capacity building at all levels, for instance irrigation technicians and irrigation agronomists, development of safety guidelines (for irrigation infrastructure) and establishment of database information centres on water resources and irrigation are the most important prerequisites for success.

Keywords

Agriculture; water; irrigation; climate change; adaptation; rainwater harvesting; Ethiopia.

4.1 Introduction

Ethiopia has a huge potential of surface and groundwater resources. However, its economy largely depends on rainfed agriculture. Long term data on rainfall in Ethiopia indicate that it is erratic, unpredictable and scarce. Drought in Ethiopia creates serious food insecurity and land degradation problems that have particularly severe impacts on the poor. Recurrent devastating drought coupled with significant soil loss due to environmental degradation has resulted in chronic food insecurity. Most of the serious drought years in Ethiopia—for example 1972/73, 1984 and 2002/03 (NMSA 2007)—are linked with rain shortages. Adequate production of food crops in the country is highly associated with good rainfall years.

Under climate change and extreme weather events, water scarcity is expected to increase and as a result water security could decline significantly in rural areas. Consequently, it is important to understand the impacts of climate change on agricultural water resources in Ethiopia and to develop adaptive capacity to respond to these impacts. To this end, efforts are being made to increase agricultural production and productivity through various mechanisms including development and promotion of small-scale irrigation (gravity and lift irrigation), water harvesting technologies (in situ and ex situ) and shallow groundwater resources for small-scale irrigation and promoting various physical and biological soil and water conservation measures.

This paper presents an overview of the current situation and trends of agricultural water management in Ethiopia and the impacts of climate change on agricultural water resources. Ethiopian experiences on selected agricultural water management practices for adaptation to climate change are also discussed.

4.2 Review of the current situation and trends

The smallholder rainfed agricultural sector is the mainstay of the Ethiopian economy and directly provides 85% of the population's livelihoods, 43% of gross domestic product (GDP), and over 80% of export earnings. According to the 1994 national census, Ethiopia had a population of 53.5 million people. The population was projected to be 83.5 and 106 million, in 2010 and 2020 respectively (MoWR 2002).

Ethiopia has a land area of 122 million ha of which 55 to 60 million ha are estimated to be agriculturally productive both for rainfed agriculture and gravity irrigation. Of the estimated

arable land area, only 30% is being cultivated. Discounting availability of water, an estimated 10 million ha of land are suitable for irrigation, with more than half of this potential land for irrigation located in the Abay River basin (MoWR 2002).

The country has a diverse climate ranging from semi-arid desert in the lowlands to humid and warm (temperate) climate in the southwest parts. Mean annual rainfall distribution has maxima (more than 2000 mm) over the southwestern highlands and minima (less than 300 mm) over the southeastern and northeastern lowlands. Mean annual temperature ranges from less than 15°C over the highlands to more than 25°C in the lowlands (NMSA 2001).

There are 12 drainage basins in the country. Most of the rivers in these basins cross the national boundary. The total available water (mean annual flow) is estimated at 112 billion cubic meters and the groundwater potential is about 2.6 billion cubic meters, while the potentially irrigable land in the country has been estimated at 3.7 million hectares (NMSA 2007). There are also eleven major lakes with a total area of 750,000 ha. Other estimates based on the estimated mean annual flow indicate that the irrigation potential in the country is estimated at 5.3 million ha which includes 3.7 million ha of gravity fed irrigation potential and an additional 1.1 million ha from groundwater (from latest estimate of 6.5 billion cubic meter of groundwater potential) and 0.5 million ha from various ex situ rainwater harvesting systems (Awulachew 2010).

Despite Ethiopia's considerable agricultural resource potential, the country has been facing chronic food shortages since the early 1970s as a result of recurrent droughts (NEPAD 2005). Climate related hazards in Ethiopia include droughts, floods, strong winds, frost, and heat waves (high temperatures) (NMSA 2007). Droughts and floods are the most important climate related natural hazards impacting the country from time to time. Recurrent droughts in the past have resulted in huge loss of life and property as well as migration of people. According to NMSA (2007), vulnerability assessment based on existing information and rapid assessments carried out under NAPA indicate that the most vulnerable sectors to climate change and variability are agriculture, water and human health. Smallholder farmers and pastoralists are the most vulnerable. Moreover, with the continuing loss of land productivity due to soil erosion (about 1.9 billion tons of soil annually) (Awulachew 2010), the situation in Ethiopia could get worse unless more efforts are made on efficient use of agricultural water resources through appropriate management of both rainfed and irrigated agriculture.

Ethiopia's Agricultural Development Led Industrialization (ADLI) strategy, the Rural Development Policy and Strategy (RDPS) as well as the Water Resources Management Policy (WRMP) give top priority to the development of small-scale irrigation and water harvesting as part of the national effort to attain food security and food self-sufficiency through efficient use of agricultural water resources (both green and blue). Large and small scale irrigation development is one of the priorities of the Ethiopian National Action Plan and the Initial National Communication Report for UNFCCC has also suggested it as one of the climate change adaptation options for the agriculture sector. To this end, water harvesting is considered as a valuable option in increasing water accessibility for agricultural production and enhancing food security as well as to minimizing the impacts of drought hazards.

The Agriculture Growth Program (AGP) has also envisaged increasing the current 853,000 ha of small-scale irrigation to 1.8 million ha by developing an additional 1 million ha during the period 2011–2015 (MoA 2010). The current irrigated area of 127 000 ha by medium and large scale irrigation implemented by Ministry of Water and Energy (MoWE), is envisaged to reach 400 000 ha during the 2011–2015 five year strategic plans (GGGI 2011). It is also envisaged to increase the current national land area of 3.7 million ha developed with physical and biological soil and water conservation measures to 4.7 million ha during the same period (MoA 2010).

4.3 Climate change impacts on agricultural water resources

Climate changes, population growth, increasing water demand, overexploitation of natural resources and environmental degradation have significantly degraded the world's freshwater resources. IPCC (2007) predicted that rain-fed crop yields in some countries will decrease by 50% and that an estimated 50–250 million Africans will face increased water stress by 2020.

The experience of moderately developed and water efficient countries shows that roughly 5 to 20 times that of the minimum index (Falkenmark et al. 1990), one hundred litres per person per day for basic household needs to maintain good health, is needed to satisfy the requirements of agriculture, industry and energy production. On this basis, a country whose renewable freshwater resource availability on an annual per capita basis of less than 1700 m³ will suffer from water stress and when freshwater availability falls below 1000 m³ per person per year, countries are likely to experience a chronic water scarcity in which lack of water begins to hamper economic development and human health and well-being. When renewable

water supplies fall below 500 m³ per person per year, countries will likely experience absolute scarcity.

Using the definition from Falkenmark et al. (1990), the situation in African countries with regard to water scarcity shows that six African countries were already in a state of water scarcity or water stress in 1990. This will increase to 16 countries by 2025. Of 20 African countries that have faced food emergencies in recent years, half are either stressed by water shortages or are projected to fall into the stress category by 2025. According to FAO (2007), agricultural production and the bio-physical, political and social systems that determine food security in Africa are expected to be under considerable additional stress due to climate change. In this regard, smallholder farmers in Africa need to adapt to climate change and climate variability.

According to IPCC (2007), climatic factors that directly affect climate change and agricultural productivity and water availability include among others: increase in average temperature, change in rainfall amount and patterns, rising atmospheric concentrations of CO₂ and change in climatic variability and extreme events. Thus, an increase in average temperature can have an impact on length of crop growing season, adversely affect crop yield, increase evaporation and transpiration rates from soil surfaces, water bodies, and vegetation surfaces, (increases in evapotranspiration) and moreover increase the chance of several droughts. While change in rainfall amount and pattern can affect the rate of soil erosion, soil moisture infiltration rate, overall impact on crop water use are also important for crop production and water resource allocation. Low soil infiltration rate means high surface runoff, soil erosion or flooding and consequently depletion of soil nutrients and siltation of water bodies such as ponds and reservoirs. These all have direct impacts on water and the livelihoods of smallholder farmers and pastoralists in poor countries including Ethiopia.

Water shortage is already a problem in many parts of Ethiopia, particularly in arid and semi-arid areas which are characterized by very high spatial and temporal variability. According to Abraham et al. (2007), for example, the climate change impact study scenarios on Lake Ziway watershed for the years 2001–2099 showed that both temperature and precipitation are likely to increase from the 1981–2000 level. The study concludes that this is likely to drop the lake level up to two-thirds of a meter (from a total depth of 4 m) and shrink the water surface area up to 25 km² (from a total area of 7300 km²). If this is combined with the unbalanced supply-

demand equation in the watershed, it is expected to have significant impacts on the lake water balance, and runoff is likely to decrease in the future and be insufficient to meet future demands for water.

4.4 Agricultural water management options for adaptation to climate change and enhanced food production

According to Mati (2007), agricultural water management is defined as “all deliberate human actions designed to optimize the availability of water for agricultural purposes” and is an integral part of many smallholder farming systems in sub-Saharan Africa. Agricultural water management includes crop husbandry, soil and water conservation, rainwater harvesting and management, irrigation and drainage, wetlands management and all aspects of land and water management. Improving agricultural water management will enhance the role of smallholder farmers and irrigators in adapting to decreased water.

This section presents some of the important technology options for sustainable development and management of agricultural water resources for adaptation to climate change targeting smallholder farmers and pastoralists in Ethiopia.

4.4.1 Rainwater harvesting and management systems

Rainwater harvesting systems offer a suitable means of agricultural water supply by upgrading rainfed agriculture through in situ soil moisture conservation and on-farm runoff storage for complete and supplementary irrigation. In addition, rainwater harvesting techniques can prevent degradation of natural resources through reduced soil erosion.

Water storage in the soil (in situ) or in any reservoir (ex situ) is widely promoted in Ethiopia as one of the options for adapting to climate change. The objective of promoting water storage systems as an adaptation strategy in smallholder farming is to reduce farmer’s climate vulnerability by increasing water availability and agricultural production (water and food security) as well as increasing future adaptive capacity. The need for water storage is highly considered in situations where rainfall is variable and unpredictable and where agricultural production and productivity are being adversely affected as a result of climate change resulting in drought and famine.

The most common macro - and in situ rainwater storage structures or techniques for crop production that are promoted in Ethiopia and are considered as options for adaptation to climate change are discussed as follows:

1. On-farm underground rainwater storage structures (water tanks/cisterns)

Small rainwater storage structures are constructed to supplement rain fed cultivation and for irrigation for high value crops in small plots not of more than 500 m². In most cases, cisterns are constructed below the ground surface in trapezoidal, hemispherical or circular shapes on stable soils. The depth of the cisterns varies from 3 to 8 m with water storage capacity of 50 to 100 m³. To minimize water loss due to seepage, rainwater tanks are lined with stone masonry, burnt bricks, ferro-cement or geo-membrane. To prevent water loss from evaporation, the structures are covered with grasses, bamboo mats, and sometimes with corrugated iron sheets (Photo 4.1). In most cases, low head gravity drip irrigation systems and appropriate agronomic practices are recommended for growing high value crops such as onion, tomato, pepper, and cabbage. The total irrigated land area in the country using small water tanks and farm ponds in 2009/2010 was estimated to be 40,000 ha (MoARD 2010). The most common problems in small rainwater tanks are the high cost per unit of water stored and the skill required for construction. However, these types of structures are promoted in areas where water is the major limiting factor for agricultural development or domestic water supply.



Photo 4.1 Underground rainwater tank in Siraro district. Credit: H. Nega, MoA

If small rainwater storage structures are used as irrigation water sources with drip irrigation, optimum irrigation regimes and suitable agronomic practices (such as mulch materials, short duration crops), the technology can significantly improve water productivity and increase smallholders' incomes. For example, field research conducted in the Rift Valley of Ethiopia to study the effect of deficit irrigation and mulch on drip irrigated onion under rainwater harvesting system by Nega (2009) indicated that rainwater tanks of 120–125 m³ capacities are recommended for the area under study as an appropriate size for a household-level rainwater harvesting system to irrigate 500 m² of farmland at irrigation scheduling of 50% of total available water with straw mulch and with expected irrigation water use efficiency (IWUE) of 11–13 kg/m³ and benefit cost (B/C) ratio of 1.74 to 2.13. In the same study, when the deficit irrigation level was increased from 0% to 25%, 50% and 75%, the yield reduction was 16%, 26% and 35% while the water saved in terms of irrigation water applied was increased by 14%, 29% and 47%, respectively. The results revealed that introducing deficit irrigation in water scarce areas can benefit more in saving irrigation water than the yield reduction. For example, at 75% deficit irrigation, the yield reduction was 35% while the water saved (47%) is higher by 10% which can be used for other purposes.

2. On-farm runoff harvesting excavated farm ponds

In Ethiopia, excavated farm ponds are very common and are the most widely used rainwater harvesting system for a drinking water and irrigation water source in moisture or water deficit areas. Excavated farm ponds are artificial reservoirs often dug below ground surface in soil, which is naturally impermeable or treated to become impermeable (Photo 4.2). The shape of farm ponds may be rectangular, square, circular or trapezoidal depending on the soil, the depth and capacity of the structure. The side slope of the embankment may range between 1:0.5 to 1:3 (vertical:horizontal) depending on the types of soil in the area. To improve the problem of water withdrawal, most ponds in Ethiopia are designed to have only a maximum depth of 4 m. To reduce seepage problems, ponds are compacted with clay or lined with high-density polythene sheet-geo membrane of 0.5 mm thick.



Photo 4.2 Excavated farm pond in Tigray Region. Credit: H. Nega, MoA

The most outstanding problem in farm pond promotion is the water loss due to evaporation since most ponds are not provided with roofing. However, to minimize water loss from evaporation especially in arid and semiarid areas, ponds are designed with minimum surface area and increased depth. Ponds promoted in Ethiopia have a water storage capacity of between 60–180 m³. The operation and maintenance of farm ponds is simple and low cost that can be managed using local knowledge and resource. Bucket lifting (rope and shadoof), treadle pump and in some cases motor pumps are used for lifting water from farm ponds.

The rate of adoption of farm ponds is generally high in Ethiopia, especially in the areas where cash crops are grown and moisture or water is a limiting factor for crop production. In Gursum District, East Harge zone, and Oromiya regional, for example, the importance of farm ponds are explained as “No pond, no wife” meaning getting a wife without owning a farm pond is unthinkable.

3. Micro dams

A dam is an artificial barrier constructed with an embankment above the ground surface to store, control and divert water for water supply and irrigation uses. The source of water could be a river, stream or surface runoff generated from a delineated watershed area. A dam can be small, medium or large in size. Small dams (micro dams) constructed in Ethiopia are normally

less than 15 meters in height, have a reservoir capacity of less than 3 million cubic meters, and are constructed from earthen materials. Small dams are mainly used in Ethiopia for small-scale irrigation purposes to irrigate up to 200 ha (Photo 4.3). Some of the dams constructed in the country are not functioning due to sedimentation, seepage or low catchment yield, in which problems related to planning, design and implementation are the root causes.



Photo 4.3 Micro dam in Tigray Region. Credit: H. Nega, MoA

4. Sand river storage structures (and/sub-surface dams)

Stream storage is another water harvesting technique through constructing barriers (earth dams, concrete dams or masonry dams) across small streams, dry river beds or gullies. The most common stream storage practiced in Ethiopia includes sand dams in dry river beds and earthen check dams in gullies. Sand dams are constructed across a dry river bed to block the subsurface flow of water, hence creating a reservoir upstream of the dam within the riverbed. The main function of a sand dam is to store water in the sand of the riverbed and therefore increase the volume of sand and water in riverbeds (Photo 4.4).



Photo 4.4 Sand dam in Yabello. Credit: H. Nega, MoA

5. Sediment storage dam

Sediment storage dams are constructed across gullies to block the surface and sub-surface flow of water, hence creating a reservoir upstream of the dam within the riverbed (Photo 4.5). The main function of check dams is reducing the impact of gully formation at the downstream side of the dam by storing the flowing water at the upstream side of the dam.

Water from the storage structure, for example in the case of sand dams, can be collected through a construction abstraction well or through a pipe system. With check dams, water is either lifted using manual or motor pumps, and conveyed by gravity for use. The other most important functions of stream storages are sand harvesting (for off-farm income generation in the case of sand dam storage), rehabilitation of gullies, and groundwater recharge (RAIN 2008). Moreover, by constructing shallow tube wells close to the dam site, it is possible to develop a good quality groundwater source that can be used for various purposes including irrigation.



Photo 4.5 Sediment storage dams in Dire Dawa Administration. Credit: H. Nega, MoA

6. Rooftop rainwater harvesting

Rainwater can be collected from various types of catchment, which include natural catchments (any land surface including rock catchment), paved ground surfaces such as asphalt roads, or from buildings having impermeable roofs such as corrugated roofs or concrete slab roofs. Collecting rainwater from rooftops has environmental advantages in which collecting rainwater is not only water conserving, it is also energy conserving since the stored water can be conveyed to the intended use by gravity (Photo 4.6).



Photo 4.6 Rooftop rainwater harvesting in Tigray Region. Credit: H. Nega, MoA

In Ethiopia, constructing rooftop rainwater tanks with a capacity of 10–60 m³ to store rainwater from rural school buildings, rural clinics and other community services buildings is very common. The structures are constructed with the available construction materials such as masonry, burnt bricks, ferro-cement, and reinforced concrete and polyethylene tanks. Though the main purpose of the structure is basically for water supply, in some cases the stored water is used for production of seedlings on small plots, watering of live fences and production of fruit trees. Rooftop rainwater harvesting can also prevent local erosion and flooding caused by runoff generated from buildings in towns or cities.

7. In situ rainwater harvesting to improve rainfed agriculture

The simplest and most cost effective possible approach in upgrading rainfed agriculture to agricultural water management (together with all agronomic options) includes moisture conservation measures, soil fertility improvement techniques, and in situ rainwater harvesting techniques. In moisture conservation techniques, rainwater is collected and stored in the soil. Planting pits commonly known as zai pits in West Africa, ridging and tied ridging, trenches, mulching, level bunds, check dams, conservation agriculture (minimum and zero tillage) are among the most common types of moisture conservation and soil fertility improvement techniques practiced in Ethiopia. In situ rainwater harvesting is collecting and transporting rainwater from a designed catchment area (uncultivated micro or macro catchments) and

storing and utilizing it in the soil to improve the soil moisture content in the designed cropping area. Semi-circular bunds (half-moon), contour ridges, contour stone bunds, contour soil bunds, conservation benches are some examples of in situ rainwater harvesting techniques practiced in many parts of Ethiopia (for example in Dire Dawa, Konso, Harage Highlands, Abrha Atsbeha in Tigray, and Sekota in Amhara).

The other important strategy in rainfed agriculture is supplementary irrigation. For example, supplemental irrigation—the watering of essentially rain fed crops with small amounts when rainfall fails to provide sufficient moisture—has been proven a drought-proof strategy in most moisture stressed areas. According to ESCWA and ICARDA (2003) as cited by Ngigi (2009), supplementing just 50% of the rainfed crop irrigation requirements in Syria reduces the grain yield by only 10–20% relative to full irrigation. Using the saved 50% to irrigate an equal area gives a much greater return in total production. The same report indicated that when the productivity of water in fully irrigated areas was compared with supplementary irrigation, the productivity is higher with supplementary irrigation in which in fully irrigated areas with good management, wheat grain yield is about 6 ton/ha using 800 mm of water per season. Thus, the water productivity is about 0.75 kg/m³, one third of that under supplementary irrigation with similar management. This suggests that water resources may be better allocated to supplementary irrigation when other physical and economic conditions are favourable.

4.4.2 Development of shallow groundwater resources for small-scale irrigation

1. Hand dug wells for micro-irrigation

Construction of hand dug wells is one of the methods used in utilizing shallow groundwater resources for various uses ranging from water supply to irrigation. Shallow wells are found in riverbanks, in runoff streams and sedimentary flood fans, and in general in the quaternary sedimentary formations where groundwater level is shallow (Photo 4.7). Depending on the prevailing conditions, the depth of shallow wells varies between 3 m and more than 100 m.

In Ethiopia, although in limited areas groundwater is traditionally used for household use and livestock watering, there has been no effort made in utilizing it for small-scale irrigation. Since 2003, a significant number of farmers at the household level (individual application) in

moisture stressed areas of Ethiopia were largely involved in the use of hand dug wells for micro irrigation to irrigate up to 1 ha of farmland. Hand dug wells in Ethiopia are usually of circular construction with a 1–5 m diameter and depths up to 30 m. Various water lifting devices such bucket lifting, pulley, shadoof, treadle pumps, hand pumps, motor pumps (suction type) and in some places electric pumps are used. Collapse of wells in heavy clay soils and light soils and limited well yields are the major problems identified in the development of hand dug wells.



Photo 4.7 Hand dug well in Amhara Region. Credit: H. Nega, MoA

For sustainability of shallow groundwater development, groundwater mapping and safety guidelines on development and use of hand dug wells are important areas of intervention. Otherwise, the current alarming practices such as over pumping around Meki and Ziway without any spacing limit between two wells, as well as with no effort in promoting technologies that can enhance groundwater recharge, will result in depletion of groundwater resources and wetlands as was seen in case of Lake Alemaya.

Case Study

Tadele Tiko is a farmer in Edo Gojela kebele, Adami Tulu Jido Combolcha district, in Oromiya region, Ethiopia. He owns 0.25 ha farm plot at his homestead on which his entire family of about 5 people depend. In the area where he lives, the depth of the water table (static) is about 9 meters and as most farmers in the area did, he had dug a 6 meter depth pit (3 meter by 4 meter) as a pump house and installed a 3" diesel pump at the foot of the underground pit (Photo 4.8).



Photo 4.8 Pump house for diesel pump

From the point of the pump position, a hole with a one meter diameter and a 3 meter depth hole was dug to have 2 meters of suction head. Then, he has planted onion on his 0.25 ha farm plot. However, with the 3" diesel, pumping was completed within three minutes time. Then, the only solution was to wait for about 2–3 hours until the drawdown was

recovered to its original position. With this condition he was frustrated seeing his crop was dying. However, at the time of site selection for practical Training of Trainers training on manual tube well drilling in Adami Tulu Jido Combolcha district, Tadele's farm was selected as a practical training demonstration site. Accordingly, a tube well with a total depth of 37.5 m (starting from the base of the 6 meter deep pump hose) was drilled. As a result, using the newly constructed tube well he was able to

pump continuously at a discharge rate of

6 l/s for about 6–8 hours per day. As reported by Tadele, he was able to harvest 8.6 tons of onions from 0.25 ha land and obtain a gross income of ETB 33,000 and a profit of ETB 22,000 ETB in three months. Immediately after the first harvest, he had planted the second time by expanding the irrigated area through renting an additional 1.5 ha (Photo 4.9). At the beginning of the main rainy season, Tadele's plot was ready for the third cultivation (rainfed



Photo 4.9 Tube well irrigated farm

cultivation) in which his effort can be a lesson of how food crop production can be increased even up to three times through introducing best practices in agricultural water management.

2. Manual tube well irrigation

Mobilization of water resources and its associated high initial cost is the most outstanding constraint in irrigation development in Ethiopia. These costs become extremely high, especially when groundwater is tapped for irrigation. The deeper the well or borehole, the higher the capital, operation and maintenance costs. For example, developing a shallow well with machine drilling for hand pumps (50–60 m deep) costs about USD 94¹ per meter depth in Ethiopia, while the cost of developing a deep well of up to 400 m (drilling, installation of casing and screening, and pump test) excluding pump installation varies from USD 353 to USD 882 per meter depth. The high cost of developing groundwater sources is a major impediment to water access for many rural people. To this end, the MoA in collaboration with World Food Programme (WFP), Ethiopia has been alternatively demonstrating manual tube well drilling for small-scale irrigation. Traditional manual tube well installation for irrigation purposes in Northern Sudan and East Asia have been used for over 50 years and are constructed manually by local artisans. From the very limited number of tube wells demonstrated in Ethiopia, the technology has proven to be successful and at a lower-cost with great potential scope of application. The manual tube well drilling technology is a practical solution for areas where the static water level is less than 20 meters deep and the sub soil formation is soft. While manual tube well drilling is not a practical solution in base rock formations, there are many areas in Ethiopia where it can effectively provide water for irrigation, especially in areas where hand dug wells are not effective due to collapsing of the wells and low well yield.

Manual tube well drilling experience in Ethiopia has shown that in soft soil formation and where static water level not deeper than 12 meters, it is possible to drill up to 51.5 meter depth with four drilling crew members, and the work can be accomplished within a period of three to six days. The only required drilling tools are 1.5” and 3” galvanized iron pipes that can be purchased from local markets. A 3” diesel pump (one option) can be fixed for the purpose of water abstraction from manually drilled tube wells. Based on the Ethiopian experience, the average drilling cost is estimated to be between USD 6–12 per meter depth. This is a fraction of the cost of conventional machine drilling and the technology is appropriate for small

¹ USD 1 = 17 Ethiopian Birr

isolated communities that will never benefit from machine drilling projects because of the limited access and high drilling cost.

4.4.3 Small-scale irrigation infrastructure development

1. Small-scale modern river/stream diversions

Modern small-scale river diversion irrigation schemes in Ethiopia are constructed with permanent structures to irrigate up to 200 ha of land. Even though the actual number of modern small-scale irrigation schemes within the country is not clearly known, they are very limited as compared to traditional river diversion schemes due to the high costs related to design, construction, supervision and maintenance. The common irrigation method in all river diversion schemes is surface irrigation, dominantly furrow type, in which the irrigation efficiency is too low (about 40–50%), leading to high water loss in unlined canals. Also, most of the time drainage facilities are lacking in which the effect can be seen in rising groundwater levels and consequently resulting in salinity problems especially in the Awash and Rift valley river basins.

2. Traditional river diversion schemes

Farming communities in different agro-ecological zones of Ethiopia are largely involved in construction and use of traditional river diversion schemes through constructing physical diversions and gully crossing structures built with local materials. Over the last decade, an increase in traditionally irrigated areas has been observed due to the growing pressure to intensify agricultural production as a result of high population growth and shortage of arable land. For example, the area irrigated with the traditional river diversion in two regions of Amhara and Tigray, up to the end of 2005/06 was estimated to be 119,800 ha while modern irrigation schemes in the same regions covered only 61,030 ha (MoARD 2006).

Moreover, traditional river diversion is an integral part of indigenous farming systems. In many places the technique can be seen also in hilly sites irrigating 0.25 to 25 ha and more. Generally, with the growing need to intensify farming systems in food insecure areas, traditional irrigation plays an important role in increasing agricultural production and improving local food security. However, the biggest problem in traditional river diversion is diversion and gully crossing structures are usually destroyed by floods during the rainy season and have to be reconstructed each year.

4.4.4 Strategies for improving agricultural water productivity to produce more crops with less water

To increase agricultural productivity per unit of land as well as per unit of water, more emphasis needs to be given to the use of efficient water saving technologies and approaches. In this regard, use of efficient irrigation technologies with other water conserving strategies as well as improving rainfed agriculture are the most important areas of intervention.

Increasing irrigation efficiency would therefore reduce the need to develop additional water supplies for all sectors by 2025 by roughly one half (Seckler and Young 1985). For example, farmers may reduce water use by applying less than full crop-consumption requirements (deficit irrigation), shifting to alternative crops or varieties of the same crop that use less water, or adopting more efficient irrigation technologies (USDA 1997). Therefore, appropriate management of irrigation water leads to conservation of water supplies, reduction in negative water quality impacts and improvement of producer net returns.

Increasing irrigation efficiency would lead to 'saved water', which can either be used to increase crop yield (expand irrigated area), allow more water for downstream users or release water for other uses. Moreover, to improve agricultural water productivity in irrigated agriculture, looking for more efficient irrigation methods such as drip irrigation is highly demanding. In drip irrigation, irrigation water is calculated only for 67% of the total command area. Hence, about 33% of irrigation water can be saved by choosing drip irrigation, while in surface (furrow, basin or border) irrigation, water is applied to the whole field. Besides saving the quantity of irrigation water (33%), all the water applied (67%) is believed to be used by plants since deep percolation and surface runoff is negligible.

The other important measures which can improve agricultural water productivity is lining of irrigation canals with appropriate lining materials such as masonry with mortar pointing and plastering, burnt brick with mortar pointing and plastering, in situ concrete lining, pre-casted concrete lining, geo-membrane lining, and pipe system. An important reason for lining a canal can be to reduce water loss, as water loss in unlined irrigation canals can be high. Canals that carry 30 to 150 l/s can lose 10 to 15% of irrigation water through seepage (Ngigi 2006).

4.4.5 Greenhouses for smallholder farmers

Climate change affects the growing environment for sensitive horticultural crops, making it necessary to grow them under greenhouses. Currently, cultivating irrigated vegetables in greenhouses is becoming popular among smallholder farmers. In irrigated greenhouse cultivation and under optimal growing conditions, vegetables and fruits can produce up to ten times more than rainfed conditions (FAO 2002). Most smallholder farmers cannot, however, afford the high investment cost of greenhouses. To address this drawback, farmers are either opting for simple locally constructed structures or taking credit from local banks or microfinance institutions to construct greenhouses.

4.4.6 Energy sources for pumping irrigation water

The common practice is that water is used to generate energy (hydropower) and energy is used to provide water. Water and energy both are used to produce crops. Energy supply for irrigation depends on the type of irrigation technology. However, to ensure selection of appropriate energy (pump system) and good performance, there is a minimum set of conditions to be considered.

In terms of pump efficiency, water-saving means a reduction in energy for supply. FAO (2002) indicated that “in most cases, switching from furrow or sprinkler irrigation systems to drip irrigation reduces water consumption by 30–60 percent.” Drip irrigation systems, especially low-head systems, use less energy than surface irrigation by emitting water at or near the root zone—increasing water use efficiency by at least 80%. Therefore, beyond the conveyance system employed to deliver water, consideration should be given to the means by which water is lifted. In Ethiopian as well as similar countries’ experiences, the following energy sources are used for pumping irrigation water:

1. Petrol/diesel engine-powered pump

The use of fuel-based pumps by smallholder farmers for irrigation during the dry season is common in Ethiopia. The pumps are used to pump water from rivers, streams, micro dams, farm ponds and hand dug wells. Four regions (Amhara, Tigray, Oromiya, and SNNPR) distributed 80,000 motor pumps between 2008 and 2011, with an estimated irrigated area of 190,000 ha micro irrigation (GGGI 2011). However, despite the wide adoption of motor

pumps, their demand for frequent maintenance and lack of spare parts are the most significant challenges.

2. Electric pump

Use of electric pumps by smallholder farmers is limited due to limited access to electricity in rural areas of Ethiopia. However, where small hydropower projects are feasible, an integrated hydropower and water supply for irrigation can be considered.

3. Solar-powered pump

Currently solar pumps for irrigation purposes are non-existent in Ethiopia. In Africa, particularly in Ethiopia, the sun is the most abundant source of energy, although not often tapped. Smallholder farmers who do not have access to a public power grid can benefit greatly from solar power.

4. Manual pumps

Treadle pumps (surface and pressurized types) and rope and washer pumps are the most common manual pump types used for lifting irrigation water from surface water sources and hand dug wells in Ethiopia. According to GGGI (2011), a total of 25,000 manual pumps were distributed and used in four regions of Ethiopia in the period of 2009–2010. This number is expected to increase by 35,000 by the end of 2011 (GGGI 2011). The biggest problem related to treadle pumps is that they are not effective in terms of durability and have high physical labour requirements. However, the money maker pump model (Kick start) which is currently produced in Ethiopia by a private company has provided better performance.

4.5 Conclusions and recommendations

Increasing investment in agricultural water management such as shallow groundwater development, on-farm and in situ rainwater storages, and small-scale irrigation schemes in Ethiopia have shown high adoption rates and resulted in increased household water security that allows households to improve their livelihoods through producing market-oriented high-value crops. However, most traditional or modern conventional irrigation systems in Ethiopia are based on labour-intensive and inefficient gravity furrow irrigation with low irrigation efficiency (under 50%). This clearly indicates that water productivity is generally low, and returns to investment are generally disappointing. This demands for investments in upgrading the existing irrigation schemes and to use and adopt advanced and sustainable water-saving

irrigation methods and technologies to enable Ethiopian farmers produce more crops with less water. It is important, however, to consider environmental sustainability and climate change implications in national and local development plans to ensure that achievement of short-term goals (in particular in areas like infrastructure investments and the use of all means of water resources) does not increase the country's vulnerability in the long term.

In general, inefficient agricultural water management in the face of climate change will make water even scarcer, with negative impacts on vulnerable smallholder farmers. Therefore, a more supportive national regulatory framework and programmes with a well-organized database and agricultural water resource information centre are required for sustainability of the current initiatives and to enhance climate change adaptation and mitigation in Ethiopia.

Findings from various studies show that public awareness of the different impacts of climate change is quite high in Ethiopia and that majority of smallholder farmers are already affected by climate-related hazards. The key priorities for adaptation to climate change on water resources as based on experience from Ethiopia and other countries include increasing investments in irrigation, rain fed agriculture, water harvesting and efficient water saving technologies in which all are aligned with policy initiatives of the Ethiopian government (UNFCCC 2001, NMSA 2007). Hence, to enhance coping capacity of smallholder farmers to climate change and variability, the following agricultural water management interventions and policies are recommended:

Agricultural water management practices

- Improve productivity of rain fed agriculture (increase crop water use efficiency) through in situ rainwater harvesting, soil moisture conservation measures, and construction of on-farm and off-farm water storage structures for supplementary irrigation;
- Develop and use shallow groundwater resources for small-scale irrigation through developing groundwater resource suitability maps as well as promoting technologies to enhance groundwater recharge (infiltration gallery, trenches, water pans, check dams, sediment storage dams, and sand dams among others);
- Improve irrigation water use efficiency through promoting water saving irrigation methods (such as gravity drip irrigation, pitch irrigation, greenhouse cultivation) and minimize conveyance water losses through lining irrigation main and secondary canals with locally available appropriate lining materials;

- More investment in solar and wind pumps for use in shallow well development.

Policy

- Investment in establishment of national water resource information centre;
- Investment in development and promotion of water storage structures and water saving irrigation technologies and improving water use efficiency in existing schemes;
- Investment in human resource development for irrigation technicians and irrigation agronomists;
- Develop safety guidelines and regulations (for water storage structures, micro dams, groundwater development and use, wetland management, cost recovery of irrigation schemes and irrigation water pricing);
- Ensure the availability and accessibility of fertilizer and improved seeds for irrigated agriculture,
- Ensure credit services in irrigated agriculture;
- Invest in agricultural extension and research on the use of new crop varieties that are more tolerant to drought.

References

- Abraham LZ, Roehrig J, Chekol DA. 2007. Climate change impact on Lake Ziway watershed water availability, Ethiopia. Catchment and Lake Research. LARS 2007.
- Awulachew SB. 2010. Irrigation potential in Ethiopia: Constraints and opportunities for enhancing the system. IWMI: Addis Ababa, Ethiopia.
- Falkenmark M, Lundqvist J, Widstand C. 1990. Water scarcity: An ultimate constraint in third world development. Linkoping University: Stockholm, Sweden.
- FAO. 2007. Climate change and food security: A framework for action. Report by an Interdepartmental Working Group on Climate Change. FAO: Rome, Italy.
- FAO. 2002. Crop and drops: Making the best use of water for agriculture. (Available from <http://www.fao.org/docrep/005/y3918e/y3918e00.HTM>)
- GGGI. 2011. Green Growth in Ethiopia: Deep drive into household irrigation technology (HIT). Draft consultancy report. Addis Ababa, Ethiopia
- IPCC. 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. Cambridge University Press: Cambridge, UK.
- Mati BM. 2007. 100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices. SWMnet. Working Paper 13. IMAWESA, SWMnet-ICRISAT, Nairobi.
- MoA. 2010. The agriculture sector five year development plan (2011–2015). Addis Ababa, Ethiopia.
- MoARD. 2010. The agriculture sector five year development plan (2006/07–2010). Addis Ababa, Ethiopia.
- MoARD. 2006. Field evaluation report on rainwater harvesting in Tigray and Amhara Regional state. Addis Ababa, Ethiopia.
- MoWR. 2002. The Federal Democratic Republic of Ethiopia. Water Sector Development Program (WSDP), 2002–2016. Addis Ababa, Ethiopia.
- Nega H. 2009. Effect of deficit irrigation and mulch on yield and water use of drip irrigated onion. M.Sc. Thesis. ABU, Zaria Nigeria.
- NEPAD. 2005. Bankable investment project profile for the Federal Democratic Republic of Ethiopia. Water harvesting and small-scale irrigation. Volume ii of vi.
- Ngigi SN. 2009. Climate change adaptation strategies: Water resources management options for smallholder farming systems in Sub-Saharan Africa. The MDG Centre for East and Southern Africa, the Weather Institute at Columbia University, New York.

- Ngigi SN. 2006. Hydrological impacts of land use changes on water resources management and socio-economic development of Upper Ewaso Ng'iro River Basin in Kenya. Published Ph.D. dissertation, UNESCO-IHE/TU Delft, Netherlands. A.A. Balkema Publishers: The Hague.
- NMSA. 2007. Climate change national adaptation programme of action (UNFCCC) of Ethiopia. Addis Ababa, Ethiopia.
- NMSA. 2001. Initial national communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). Addis Ababa, Ethiopia.
- [RAIN Foundation] Rainwater Harvesting Implementing Network. 2008. A practical guide to sand dam implementation: Water supply through local structures as adaptation to climate change. (Available from http://www.rainfoundation.org/fileadmin/PublicSite/Manuals/Sand_dam_manual_FINAL.pdf) (Accessed on 1 July 2011).
- Seckler D, Young RA. 1985. The choices of irrigation technologies in California. *American Journal of Agricultural Economics* 67:2.
- USDA. 1997. Agricultural resources and environmental indicators, 1996–97. Agricultural Handbook No. 712. Economic Research Service, United States Department of Agriculture. (Available from http://www.ers.usda.gov/publications/ah-agricultural-handbook/ah712.aspx#.Ucwf_fnl2So) (Accessed on 27 June 2013).

5. Sustainable land management technologies and approaches for climate change adaptation and mitigation

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Abstract

Scaling up successful land management practices helps to counter environmental degradation, addresses climatic change and tackles obstacles to sustainable economic growth. Despite enormous efforts and investments by the government of Ethiopia through watershed and extension approaches, lack of coordination coupled with lack of essential policies, lack of adequate technical and financial input, doubts about tenure security and low awareness of the general public have produced unsatisfactory results.

Currently, the government is addressing the bottlenecks hindering scaling up of sustainable land management (SLM) best practices. A variety of SLM technologies and approaches that can help reduce environmental degradation and improve livelihoods have been screened from those documented to be scaled up. The technologies, practices and approaches selected for scaling up are broadly classified into four categories: introduced technologies, vegetative and agronomic indigenous practices, combined physical and vegetative practices, and agronomic and vegetative measures for improving grazing lands. Mass mobilization, participatory local planning and incentive based watershed management are among the approaches used for implementing land management activities.

Opportunities for up-scaling sustainable land management practices exist. There is documentation of a number of proven and demonstrated traditional and introduced technologies, and institutions with experience and manpower to execute SLM programmes. International donor and UN agencies exist to support SLM implementation, and communities and individuals are willing to engage in SLM activities. The willingness of the government to mobilize the public and provide resources to upscale SLM activities and the willingness of

land users to mobilize their own resources all provide opportunities for making SLM a success.

Keywords

Sustainable land management; climate change; adaptation and mitigation.

5.1 Introduction

5.1.1 An overview of land degradation in Ethiopia

Ethiopia has had serious ecological and environmental imbalances during the past couple of decades due to large scale deforestation, cultivation on steep slopes and marginal lands, depleted soils and water resources and climatic irregularities. This has resulted in a large area being degraded to an irreversible level of damage. Land degradation is a major contributor to declining agricultural productivity, depleting water resources due to increasing sedimentation in reservoirs, recurrent floods, and food insecurity.

Land degradation is the reduction in the capability of the land to produce benefits from a particular land use under a specified form of land management. In Ethiopia, the various degradation processes that have contributed to loss in productive capacity within the country's ecosystem resources can be grouped into the following major land degradation types: soil degradation, vegetation degradation, biodiversity degradation, water resource degradation, and climate deterioration.

The key processes that result in the degradation of a soil's hydrological properties include water-logging and aridification. Vegetation degradation is manifested in reduction in vegetative biomass, reduction in vegetative ground cover, reduction in the quality of the vegetative biomass, decline in number of plant species and degradation of individual plants.

In Ethiopia, about 27 million ha or almost 50% of the highland areas, is considered to be significantly eroded. Of this area, 14 million ha are seriously eroded, with over 2 million ha are beyond reclamation. About 80% of the country's land surface is prone to moderate or very severe soil degradation. For the highland areas, erosion rates have been estimated to average 35 tons/ha/yr, while the estimated rate from the croplands is 130 ton/ha/yr. This has led to the conclusion that almost half of Ethiopia's annual soil losses come from the land under cultivation even though this covers only 20% of the country.

There are several factors that aggravate soil erosion in Ethiopia. Among these are lack of awareness on land degradation, lack of knowledge on how to control soil erosion, extensive use of croplands without replenishing soil nutrients, cultivating on steep slopes and marginal lands, improperly designed and constructed roads, improperly constructed drainage ways including improperly designed land management measures, out-dated farming practices and

technologies, inadequate resources (financial and skills) to invest on land, and a large population making a livelihood from the land.

The estimated annual direct cost of land degradation in Ethiopia is 3% of the agricultural GDP (Berry 2003). Inherently fragile soils, undulating terrains, erosive rains and environmentally destructive farming methods practiced by many land users have been accelerating soil erosion, which is the main contributor to land degradation. In addition, nearly one-third of the agricultural land is moderately to strongly acidic because of damaging farming practices.

5.1.2 Efforts to mitigate land degradation in Ethiopia

In Ethiopia, past efforts to address the problems of land degradation and declining land productivity have failed. The major bottleneck to improve land productivity has been the lack of commitment by land users and the decision makers to implement the policies and proclamations in place. Free-grazing animals have been the main cause for low survival rates of vegetative measures practiced in several land management projects and programmes. Physical measures including terraces, check dams and bunds have been removed or trampled as livestock move openly and graze on the land.

Scaling-up has not occurred because of various factors such as lack of adequate technical and financial inputs, doubts about tenure security and past experience with frequent land redistribution, farmers' concerns about the relatively high cost of adopting some of the best land management practices, and weak mechanisms to deliver good management practices to farmers through the research and extension system. It is important that good management practices are disseminated more widely to enhance long-term food security which is currently under threat from land degradation.

The Ethiopian Strategic Investment Framework for Sustainable Land Management (ESIF-SLM) is designed with the aim of overcoming the bottlenecks and enhancing the scaling up of best land management practices (MoARD 2008). The ESIF-SLM framework provides guidance for harmonization of approaches and efforts through increased partnership, alignment and promoting awareness of the general public. The SLM programme emphasizes scaling up successful practices, approaches and technologies to prevent or control land degradation.

5.2 Review of the situation

5.2.1 History of land management in Ethiopia

Sustainable land management is a deliberate process through which degradation can be halted or reversed. It also refers to actions of land users, individually and/or collectively to care for and manage their local land resources to obtain an optimum range of products of social and economic value. Land management practices were introduced in the northern regions of Ethiopia primarily through the Food for Work Programme launched in 1973. The Extension Programme Implementation Department (EPID) of the MoA also introduced new ways of managing land in other parts of the country in the late 1970s and early 1980s.

The Soil and Water Conservation Department was established in 1980 with responsibilities for coordinating the implementation of the National Soil and Water Conservation Programme. Systematic and planned activities in land management through the watershed approach were launched with the creation of the department. Watersheds ranging from 20,000–40,000 ha were planned and implemented through an incentive-based watershed approach.

Sustainable land management activities are currently being broadly undertaken through various projects, programmes and government extension programme. The following are some of the SLM projects and programmes being implemented in various areas by different organizations.

- The Productive Safety Net Program being implemented by the government of Ethiopia with financial and technical support from development partners since 2005. The programme focuses on land management through the watershed approach.
- The MERET project of the MoA, supported by WFP is a pioneer project that started implementing land management activities some 30 years ago through a participatory community based watershed management approach in mini-watersheds of about 500 ha.

Other SLM initiatives include:

- SLM projects supported by the German Development Cooperation;
- SLM projects supported by the World Bank and includes the Food Security project, Productive Safety Nets project, Pastoral Community Development projects (phases I & II), the Rural Capacity Building project, Irrigation and Drainage project, Sustainable Land

Management project, Tana and Beles Integrated Water Resources Development project, and Nile Basin Initiative;

- SLM activities supported by the International Fund for Agricultural Development (IFAD) in the Participatory Small-scale Irrigation Development program, Pastoral Community Development project, and Community-Based Integrated Natural Resources Management project in Lake Tana Watershed project, and
- SLM activities supported by the African Development Bank (AfDB) through the Agricultural Sector Support project.

5.2.2 Factors hindering scaling up of land management practices

Free grazing, which is rampantly practiced in Ethiopia, has been negatively affecting land management initiatives. Free grazing of livestock has caused low survival rates of vegetative measures for land management. Physical measures such as terraces, check dams and bunds have been removed or trampled to collapse as livestock are given free access into areas with these measures. In the highlands, the expansion of grazing beyond the land's carrying capacity occurs at the expense of the remaining natural vegetation, further accelerating land degradation. The scarcity of grazing land and livestock feeds has forced the widespread use of crop residues to feed livestock. When crop residues are removed for feed and cow dung is used for fuel, the soil loses its organic matter and nutrients. This breach in the soil nutrient cycle seriously depletes soil quality, increases erosion, and eventually reduces soil productivity.

Nearly 95% of the Ethiopia's energy consumption comes from biomass fuels, resulting in the cutting of trees. Deforestation has been taking place excessively, ultimately stripping the land of its vegetative biomass and exposing it to high levels of soil erosion. Land tenure insecurity has factored into the increasing land degradation problem in Ethiopia. It undermines land users' motivation to invest in sustainable land management practices. In the past few years, however, the federal and regional governments enacted land use and administration policies which give holder rights for land users and also provides them with a user rights certificate which is known as the first level certificate.

Until very recently, the unsatisfactory achievements in implementation of the proclamation for land administration and land use have been the major factors undermining sustainability of

land management measures. However, there are related policies developed by other agencies and ministries such as the environmental policy, water sector policy and the conservation strategy, but their contribution to the realization of sustainable land management has been very limited.

Uncoordinated efforts coupled with the lack of essential policies have resulted in unsustainable land management interventions in the past, though a lot of effort and investments were made through the watershed and extension approaches. Lack of appropriate technologies coupled with sound approaches for implementing even the few good practices that have demonstrated to be effective in a few areas was another bottleneck that hindered adoption by land users and suitability of the measures in various agro-ecological zones in the country.

The major bottleneck to sustainable land management has been lack of commitment at all levels to implement the policies and strategies in place. Policies that have direct bearing on natural resources management such as livestock, forestry and rangeland management were required to be developed and implemented as these are indispensable for sustainability and impact of land management to maintaining sound environment and improving agricultural productivity.

5.2.3 Approaches to land management

Among the approaches used for implementing land management activities in Ethiopia, the most notable one is the mass mobilization approach which was started in Tigray in the early 1990s. Other approaches used include the participatory local level planning approach, community infrastructures, self-help and incentive based watershed management approaches.

These approaches in general help to enhance the participation of all land users in planning and implementing land management activities collectively, in groups or individually by mobilizing labour and material needed for the work, provide effective technical and material support to implement planned activities and monitor results and outcomes more systematically.

Improving incomes and livelihoods by way of backyard and homestead development, income generating packages which involve engagements of land users in growing high value trees and planting crops, beekeeping and small stock rearing were introduced as an entry point to

watershed management with the emergence of the Community-Based Participatory Watershed Management Guideline (CBPWMG) which focuses on mini-watersheds (200-500 ha) as a unit of planning and implementation. Currently, most projects and programmes are using the CBPWMG for planning and implementing SLM activities.

5.3 Sustainable land management and its impact on food security and climate change

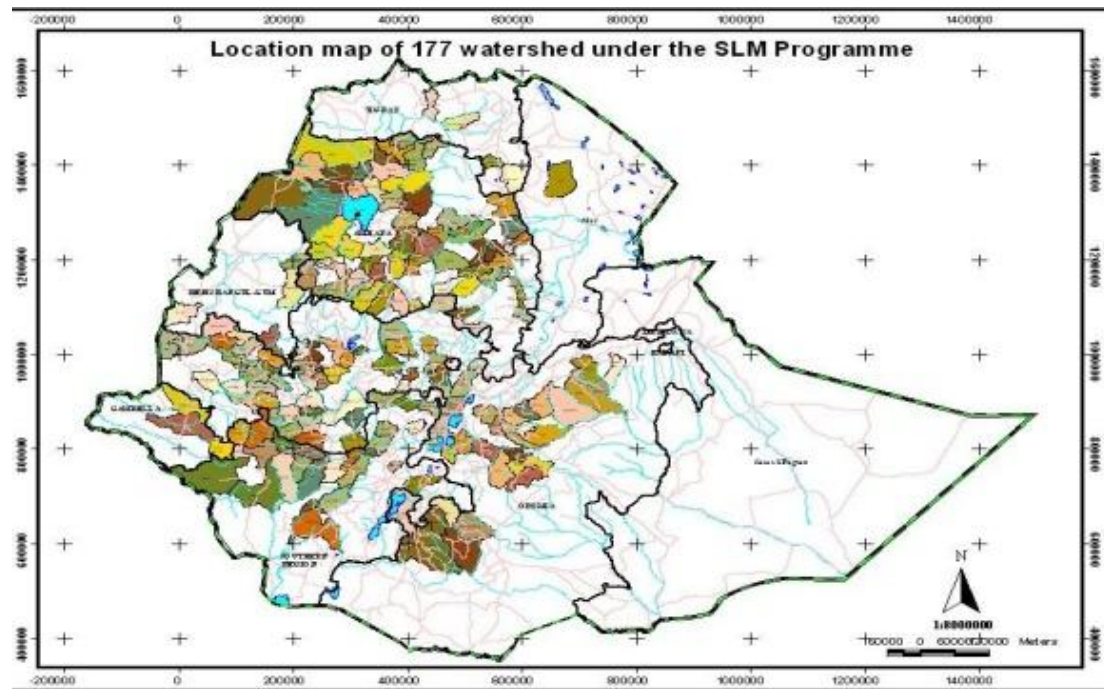
Sustainable land management requires Ethiopian land users, individually and/or collectively, to care for and manage their local natural resources (soil, water, animal and plant resources) to obtain an optimum range of products of social and economic value, while preserving, restoring and/or enhancing their productive capacity and ecological functions and services, for present and future generations. The guiding principles in tackling land degradation and promoting sustainable use of Ethiopia's land resources under the SLM framework include ecological sustainability, social and cultural sustainability, economic sustainability, livelihood sustainability and institutional sustainability.

5.3.1 The sustainable land management programme

Ethiopia is implementing a sustainable land management programme (SLM) which is aimed at enhancing improving the function of the ecosystem. It is envisaged that the SLM programme will help to increase incomes of land users by implementing activities that improve soil quality and activities that help in generating household incomes. The MoA is engaged in coordination and implementation of SLM activities in watersheds (Figure 5.1).

The SLM project aims to make agriculture more productive and sustainable, and to take advantage of opportunities for natural resource conservation to promote growth and poverty reduction. The higher-level objective of the SLM project is to provide assistance to smallholder farmers to adopt sustainable land management practices on a wider scale in order to reverse land degradation in agricultural landscapes, increase agricultural productivity and income growth, and protect ecosystem integrity and functions.

Figure 5.1. Watersheds under SLM programme in Ethiopia



The development objectives of the SLM project are to reduce land degradation in agricultural landscapes and improve the agricultural productivity of smallholder farmers. Indicators of success include:

- Percentage increase in area under sustainable land management practices in targeted watersheds;
- Percentage increase in agricultural productivity for dominant crops and livestock;
- Percentage increase in the amount of carbon sequestered;
- Percentage of development agents and Woreda experts using information on best management practices in sustainable land management; and
- Percentage increase in the number of beneficiary farmers with a sense of tenure security compared with non-beneficiaries.

Some essential prerequisites for scaling up successful SLM technologies and approaches at the community level include active community-based participation, leadership, social capital, secure land user rights, controlled livestock grazing, supportive policies, ecosystem and cultural diversity, quick and tangible benefits, low risk of failure, and market opportunities.

Innovative and appropriate technologies offer a range of options rather than single standard solutions, avoid perverse incentives, and address the root causes through multi-sectoral and integrated approaches.

5.3.2 SLM technologies and practices

The Ethiopian Overview of Technologies and Approaches (EthiOCAT) Network of the MoA has documented 52 traditional and introduced land management practices and 27 approaches in the country (Dale 2010) across the various agro-ecological zones in Ethiopia. Some of these technologies and practices have been evaluated on the basis of agro ecological applicability, scope for scaling up and the high level of adoption and adaptation. Thirty-three technologies and eight approaches were screened for scaling up. These include stone check dams and terraces (DewaChefa), contour stone bunds (Tigray), graded soil bunds and relay cutoff drains (Hossana), Desho-Bund, integrated land management measures with area closures (Alaba), and stone bunds (North Shewa). Others include ridges and furrows (Harerghie), broad basin and ridge (Harerghie), trashlines (Wozeka/ Derashe), multiple cropping (Konso), crop residue and stone mulch management (Konso), ridge basin (Konso), and chat strips and rectangular bunds (Harerghie).

5.3.3 Approaches for scaling up of successful practices

Among the approaches used for implementing land management activities in Tigray is the mass mobilization approach which has been in use for nearly 20 years. Other approaches include participatory local planning and incentive based watershed management. The objectives of these approaches are to enhance the participation of all land users in planning and implementation of land management activities collectively, in groups or individually by mobilizing labour and material needed for the work, to provide effective technical and material support to implement planned activities, and to monitor results and outcomes more systematically.

Successful interventions to prevent or control land degradation require integrated and cross-sectoral approaches to sustainable land management. Development partners have developed interest in catalysing the use of the resources they make available to leverage additional funds from bilateral and multilateral development agencies.

5.3.4 Mechanisms for coordination and scaling up SLM

The ESIF-SLM provides guidance for coordination of all SLM efforts. It provides a holistic and integrated strategic planning framework under which government and civil society organizations can work together to remove the barriers and overcome the bottlenecks to promoting and scaling up sustainable land management in Ethiopia.

Land degradation is a multi-dimensional problem, which the piecemeal past efforts of different agencies have failed to tackle effectively. The ESIF-SLM calls for an alternative approach based on multi-sectoral partnerships in which the different stakeholders seek to harmonize and align their investments in a collaborative manner with the aim of alleviating rural poverty through restoring, sustaining and enhancing the productive capacity, protective functions and biodiversity of Ethiopia's natural ecosystem resources.

The framework advocates for large scale SLM engagement in Ethiopia to reverse land degradation, improve land productivity and ensure food security for smallholder farmers. Mechanisms for enhancing SLM adoption and scaling up include enhancing partnership, creating an enabling environment, increasing implementation of best practices, practicing policies and strategies, improving extension systems, enhancing awareness promotion among land users and the public in general, increasing investments, applying community-based and integrated approaches, developing proper institutional mechanisms and mainstreaming SLM, applying improved monitoring and evaluation methods (result based monitoring and evaluation) and implementing land tenure policies favouring investments on land.

5.3.5 Opportunities for scaling up SLM

Scaling up is dependent on putting in place measures, practices and associated investments that can work in synergy to expand uptake of SLM in a rapid and cost effective manner at higher scales as appropriate. Successful up-scaling and mainstreaming of sustainable land management requires that we learn from our past and transcend to our next best thinking—including what has worked and abandoning what no longer serves us.

Opportunities for scaling up sustainable land management practices exist and include:

- Availability of a number of proven and demonstrated traditional and introduced technologies;

- Institutions which have experience and human resources to implement SLM programmes;
- International donor institutions and UN agencies to support implementation of SLM and conventions;
- Communities and individuals willing to engage in SLM;
- Readiness of the government to mobilize the public and resources to scale up SLM activities; and
- Willingness of land users to mobilize their own resources.

The SLM coordination platform is another opportunity created by the government. The platform is created to encourage discussions among SLM stakeholders and actors and aims at avoiding duplication and promoting synergies.

In 2006, the government established a mechanism to coordinate all SLM investments in Ethiopia. This mechanism comprises of a national steering committee chaired by the State Minister for the Federal Ministry of Agriculture and Rural Development (MoARD); a national technical committee that comprises representatives from government, civil society, and development agencies; and an SLM Support Unit. Furthermore, MoARD has developed a Country SLM Investment Framework which outlines key priorities for SLM investments and a strategy for scaling up.

5.4 Sustainable land management in climate change adaptation and mitigation: policies and strategies

Viable strategies and effective policies and approaches are needed to enhance scaling up of best practices in the different agro-ecological zones with varying sociocultural, farming systems, biophysical and policy settings. Previous studies indicate that several problems constrain the scaling up of land management practices in Ethiopia. Some of these include socio-economic concerns, policy, cultural practices, approaches, appropriateness of the technologies and sticking to poor land management practices. The problems vary in magnitude and scale in different areas and agro-ecological zones. Land management practices have shown low adoption, adaptation and replicability in high rainfall areas but are well adopted and expanded in low rainfall areas (Dale 2010).

5.4.1 Policies

Sustainable land management puts emphasis on integrated measures that would result in improved livelihoods and ecosystem functions. In order to address these goals, proper strategies and policies need to be developed and implemented. Sustainability can be achieved only through the collective efforts of those immediately responsible for managing resources. This requires a policy environment that empowers farmers and other local decision makers, to reap benefits for good land use decisions, but also to be held responsible for inappropriate land use.

Efforts to implement natural resources management practices occurred with many actors involved in natural resources management and land conservation. Owing to uncoordinated efforts, varying and often contradicting approaches and lack of framework for harmonizing efforts and approaches have been seriously undermining the effort in land management. Reports show that several actors in land management followed conflicting approaches to implement land management activities in the country and this resulted in divergence of approaches that were in contrary to coordinated efforts.

Lack of coordination among the various initiatives and absence of properly designed scaling up mechanisms greatly hindered sustainability and scaling up of SLM. Considering this as an obstacle for expanding good land management practices the MoA in collaboration with development partners and stakeholders developed a guideline—CBPWMG—which aimed at resolving the conflicts of contradicting approaches and harmonizing of technologies.

Developing and effectively implementing policies in land use and management are of crucial importance for SLM to be scaled up. Outdated cultivation practices, improperly designed and constructed rural roads, deforestation by bushfires and cultivation on steep slopes are among factors that have contributed to unsustainable use of natural resources. It is essential to develop proper policies that are able to tackle the barriers to scaling up SLM. Among the most essential policies are the land use and administration policy, livestock policy, incentive and market policies. The Land Administration and Use Proclamation of Ethiopia stipulate that land users have user rights on the land they hold and have responsibilities to manage it and maintain its productivity.

5.4.2 Strategies for scaling up successful practices

Some of the strategies to be pursued for effective and efficient implementation of sustainable land management are discussed below.

Awareness promotion is needed in communities to make them understand that environment-conscious development is crucial to poverty reduction. Also, contributing to household food security through environmental management and protection measures is a key entry point.

Communities and land users need to know SLM interventions increase real income of households through environmentally friendly interventions and improve quality of life through the provision of community operated and managed land management practices

Acceptable approaches for implementing SLM: Various actors in land management have used different approaches for implementing land management measures. The most commonly used approaches include food for work, cash for work, mass mobilization, infrastructural support, extension, self-help, land users groups or Debo (Dale 2010). The MERET project supported by WFP uses food for work as an approach for land management activities. The European Commission-assisted land management project of the 1980s used cash for work for implementing activities in land management. A number of NGOs involved in land management use food and cash payments to get land users to participate in land management activities. Food is given as a wage payment and some used food as an incentive for participation. Wrongly perceived and introduced incentives caused dependency and in the absence of these incentives it was difficult to get land users to participate in land management activities. Only a few projects which used food as an incentive for motivating land users participation were able to some degree to reduce dependency on it.

Agricultural growth strategies: The government recognizes that any strategy for alleviating rural poverty and food insecurity should be based on generating agricultural growth, with the aim of transforming the agricultural sector from subsistence to commercial production. To this end, the government has also launched a series of development and poverty reduction programmes, including the Agricultural Growth and Rural Development Strategy and Program (2004), the Food Security Program (2004) and the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP in 2006) and currently the Growth and

Transformation Plan (GTP). In all these endeavours, agricultural growth, food security and accelerated rural development constitute key government policy directions.

Community ownership: Assets developed communally and privately need to be totally owned and managed by the communities and individual land owners who developed them. Enclosure areas were in the past protected largely by site guards and in some cases by the community members themselves. Site guards are expected to guard many hectares, in which case the guarding task was often cumbersome unless the community members supported them in discharging this responsibility. Studies show that community members should benefit from the grass and the other benefits coming from the enclosures if sustainable area closure management is to be realized. Enhancing productivity of enclosure areas is very important in view of improving the carrying capacity of the land under rehabilitation. In this regard rehabilitation plans should consider the future intended land use and apply appropriate measures according to the needs of the intended land use.

Maintenance: Maintenance is essential to all sustainable land management measures. For maintenance work on cultivated lands, land users should assume the responsibility for measures placed on their land if the damage is minor and caused by carelessness, but if the damage is of a larger magnitude, a group of land users organized in land management teams or the community should assume the responsibility for the maintenance. Areas where communities and land users have been maintaining the SLM measures have attained a high sustainable development and are food secure.

Technology generation and dissemination: This could be achieved by increasing the capacity of service providers in SLM, promoting integrated service provision to maximize SLM at the villages, and strengthening land user-extension-research linkages to generate appropriate SLM technologies. Sound land management plans consider the practicing of water harvesting structures in their appropriate locations. Farm ponds, water tanks and small earth dams are among the major water harvesting structures considered in this case. Improving pastures and grazing lands should be considered as a priority livestock management policy in land management endeavours. Fuel wood plantations at villages and seeking other alternate energy sources should be considered to reduce deforestation.

Integrating physical and biological measures: Constructing physical structures alone is not an end to SLM but it is just the first measure to control soil erosion and runoff moving from one

strip to the other and it even does not control erosion taking place within the terraces.

Combining trenches with soil bunds ensures increased runoff retention and hence increased soil moisture.

Soil fertility management: Improving soil fertility is to be viewed from two perspectives in land management. One aspect is improving productivity and the other is building of soil resistance to erosion. When soil fertility is improved, its structure is improved and it develops resistance to erosion because of soil particles aggregation. Biological land management measures, agronomic measures and cultural practices, which improve soil fertility, are to be considered in this case.

Soil nutrient mining is very high in the traditional farming practices in Ethiopia. Crop residues are completely removed for livestock feed and fuel. Livestock dung is collected and dried in cakes for household use as fuel or sold in the market for the same purpose. In the highlands of Ethiopia, in particular, animal dung is the main source of fuel and is even sold in the markets. The use of animal dung for fuel has seriously affected fertility of soils not only in the backyards but it has also affected grazing and farmlands as well because dung is collected from anywhere it is found.

Purposeful and effective gully treatment: Prior to treating gullies, proper planning becomes necessary and it should take into account the purpose for which the gully is to be rehabilitated. The choice of treatment measure should be made based on future intended use of the gully. If the gully is to be used for growing crops after rehabilitation, then the type of structural and vegetative measures to be applied should be different from the ones to be applied if the gully is to be used for tree plantation or grassland development. Gullies can further be developed for waterways in which case the treatments are different accordingly.

5.5 Conclusions and recommendations

The launching of the Ethiopian Strategic Investment Framework and the initiation of various projects and programmes in land management have helped to achieve better results in sustainable development compared with past programmes that lacked systematically designed approaches. The framework facilitated establishment of proper ground to harmonize approaches and improved stakeholders' alignment for increased collaboration. Furthermore, it

boosted community mobilization and awareness and helped in increased financial and technical resources.

The government is playing a leading role by adopting appropriate policies and strategies. Increased interest from development partners and donors, availability of best practices which are to be scaled up, availability of clear guidelines (technical and strategies), commitment of the government to mobilize resources and communities, and empowerment of the Woreda are some components of the enabling environment put in place. SLM measures have greatly helped in increasing resilience of land users to climatic shocks and carbon sequestration.

References

- Berry L. 2003. Land degradation in Ethiopia: Its extent and impact. Commissioned by the GM with WB support. (Available from ftp://ftp.fao.org/agl/agll/ladadocs/ETHIOPIA_LD_CASE_STUDIES.doc) (Accessed on 5 August 2013)
- Dale DD. 2010. *Sustainable Land Management Technologies and Approaches in Ethiopia*. Addis Abeba: EthiOCAT Network, Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development.
- [MoARD] Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development. 2008. *Ethiopian Strategic Investment Framework (ESIF)*. SLM Secretariat.

6. Agrometeorological advisory system for climate change adaptation in Ethiopia

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Abstract

This paper reviews the status of agrometeorological services in particular and meteorological services in general in Ethiopia. Ethiopia needs to adapt its agricultural system to the emerging challenges of climate change. The paper also examines how an effective agrometeorological extension service to rural communities can be an important component in developing climate change adaptation options in the agricultural sector. A good climate database is indispensable to make a sound assessment of the observed climate changes and climate projections for different parts of the country, which are important for the development of location-specific adaptation options.

In Ethiopia, climate variability is one of the major factors affecting agricultural production, and the impact on the agricultural sector will be compounded more as a result of climate change. The composite average of 19 General Circulation Models (GCMs) predict for A1B (balanced emission scenario) a 1.7–2.1°C increase in Ethiopia's mean temperature by 2050. Rainfall projections show an increase in the annual rainfall, with changes in the seasonal patterns of the rainfall, which can greatly affect rainfed agriculture in the country. Unstable patterns in rainfall seasonality underscore the importance of improving access to current agrometeorological information, forecasts and advisories by the farmers to inform farm level decision making and to maximize their production and reduce production losses. This requires improving agrometeorological information, forecasts and advisories, including a critical review of the status of agrometeorological services in the country, as there is a strong need for capacity building in this area.

Finally, a general framework is given on how agrometeorological advisory services can be integrated in the country's agricultural extension services so that it can be an important component of the climate change adaptation activities.

Keywords

Climate change; adaptation; agrometeorology; forecasts; advisories.

6.1 Introduction

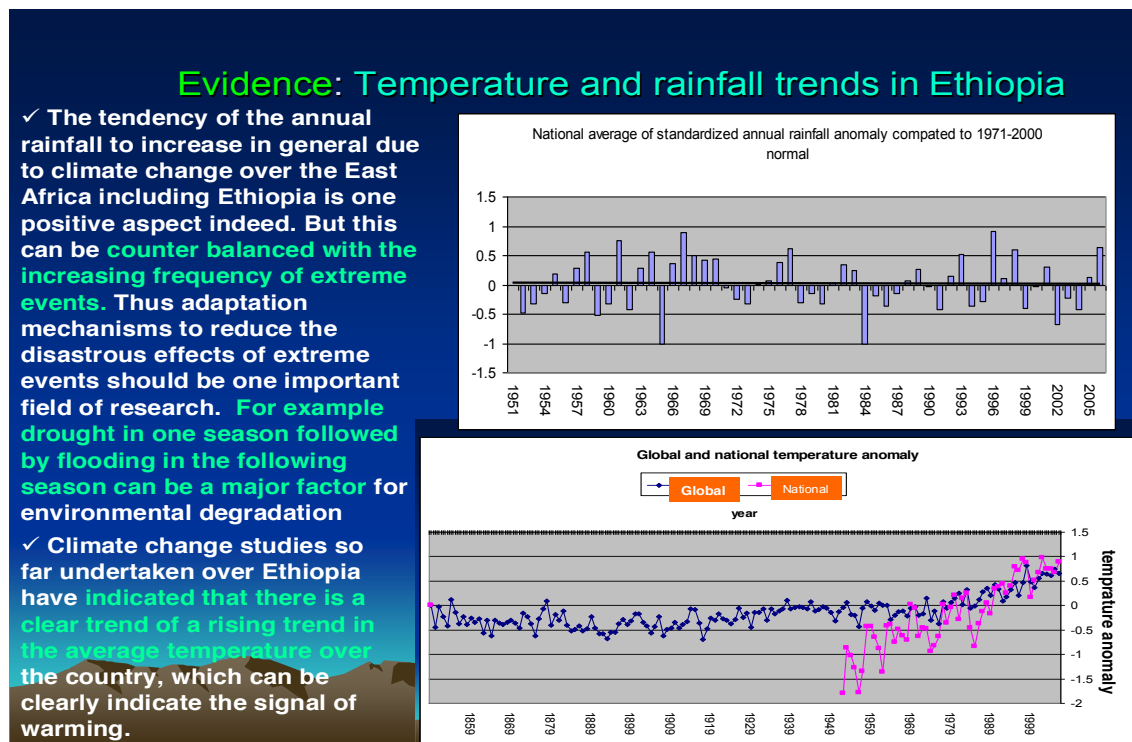
When we consider climate change, it is important to recognize the socio-economic value of our climate as a resource. Thus it is of paramount interest how we can best utilize this resource in the light of climate change in the agricultural sector. If we consider that climate is a resource, then the climate services related to it must be recognized as crucial for using this resource in the best possible and most efficient manner. This service, therefore, needs a critical review.

The major evidence for global warming has been a steady rise in the global mean surface temperature—by about 0.6° C over the last 100 years. With regard to the spatial and temporal patterns of precipitation, there has been an increase in heavy precipitation and a decrease in light precipitation. Night temperatures have increased by two-folds compared to day-time temperatures. The global sea level has risen by between 10 and 20 cm over the last 100 years, where much of the rise is attributed to an increase in global mean temperature. Since 1850, most of the world's glaciers have been retreating (Obasi 2003).

Average mean annual minimum temperature from 40 stations throughout Ethiopia for the period 1951–2006 shows that there has been a warming trend over the last 55 years (Figure 6.1). Temperatures have been increasing by about 0.37° C every decade. During the same period, mean annual rainfall variability and trend observed shows that the country has experienced both dry and wet years. The trend analysis of annual rainfall also shows that rainfall remained more or less constant when averaged over the whole country (NMA 2007).

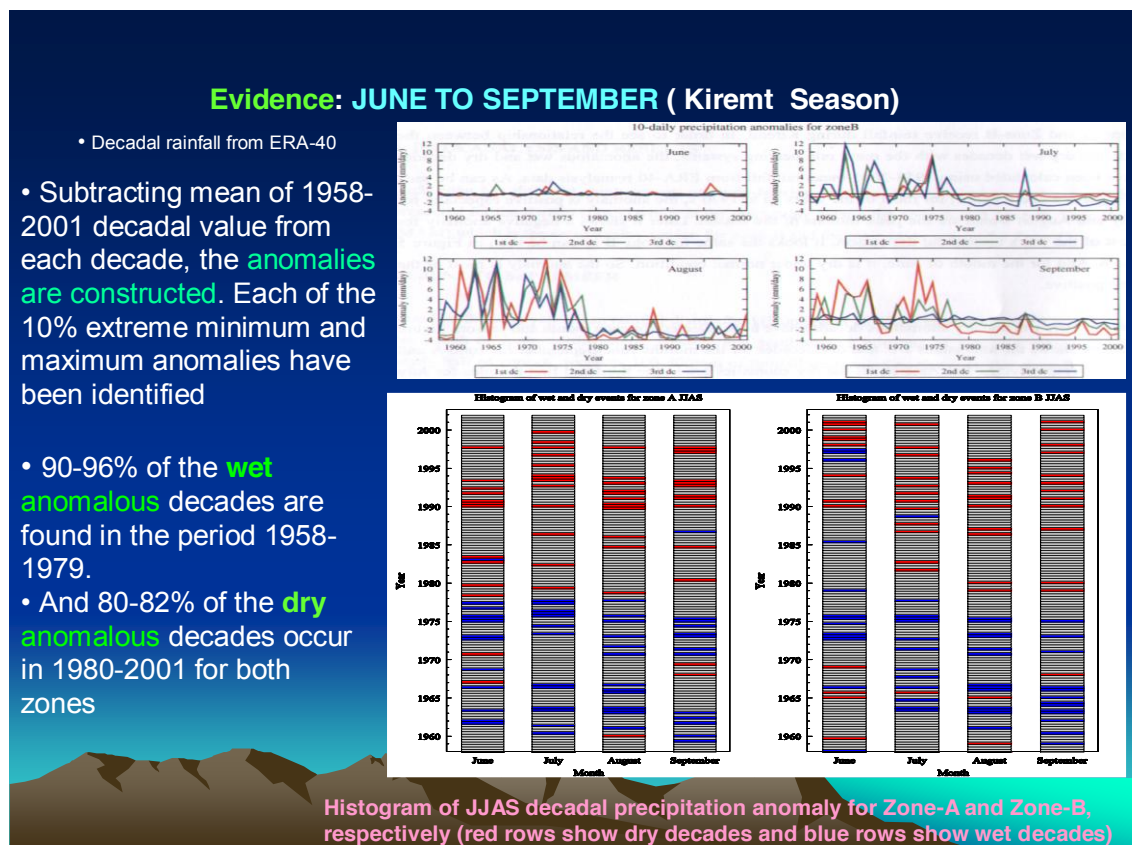
Though the annual rainfall in the country does not show a clear trend, there are various studies which have indicated a rising trend in the frequency of extreme weather events over the country. This is expected to have a more negative impact over the sub-humid and semi-arid areas of the country, including the Rift Valley and the agropastoral (Gebru and Tadege 2010) (Figure 6.2).

Figure 6.1. Temperature and rainfall trends in Ethiopia (1951-2006)



Source: NMA 2007

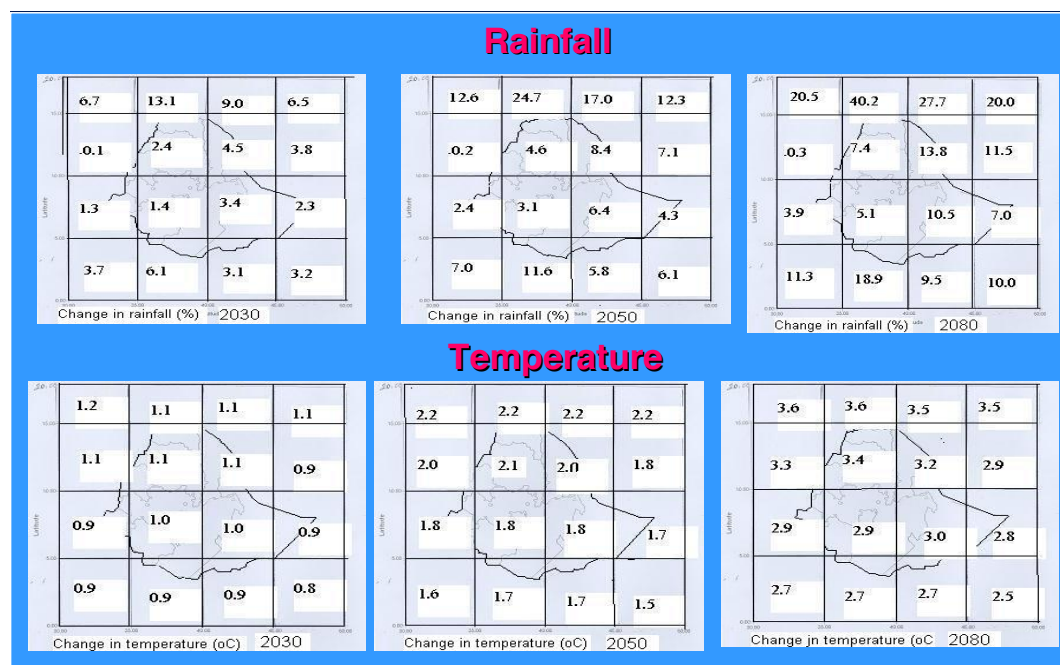
Figure 6.2. Increasing occurrences of extreme weather events



Source: Gebru 2007

According to the National Meteorological Agency (NMA 2007), long-term climate change in Ethiopia is associated with changes in precipitation patterns, rainfall variability, and temperature, which could increase the frequency of droughts and floods in the country (Figure 6.3).

Figure 6.3. Climate change projections in Ethiopia



Source: NMA 2007

Though rainfall projection shows an increase in annual rainfall, a changed pattern in the seasonality of the rainfall has been found, which requires greater adaptation options for rainfed agriculture. The effectiveness of adaptation options for different parts of the country, however, largely depends on correct assessment of the observed climate variability, trend, the climate change signals and projections for the different parts of the country. This undoubtedly requires good quality climate database and improved of climate research, which to a large extent depends on the state of development of meteorological service.

A more unstable pattern in the seasonality of the rainfall means that there will be greater dependency of farmers on agrometeorological information, forecasts and advisories so that they can better cope and adapt to the changing climate and increase their resilience. A meteorological service which strives to become part of the climate change adaptation process requires a good station network, a sound climate database and the state of the art in data

analysis, interpretation and forecasting, that can address the interests of the farming community.

This paper reviews the current conditions of meteorological services in Ethiopia and examines how meteorological services can be integrated in the general framework of climate change adaptation activities in the agricultural sector. A general review of the agrometeorological information system is discussed in section 6.2, including an assessment of the meteorological station network, database data analysis, forecasting, agrometeorological advisories and finally the status of basic climate research in the country. Section 6.3 discusses the implications of climate change. In section 6.4, key points for developing adaptation and mitigation strategies in terms of the agrometeorological information system are explored. Further, integration of agrometeorological information system with the agricultural extension services is discussed, with an emphasis on how farmers can benefit from using this information.

6.2 Review of the agrometeorological information services in Ethiopia

Scientific observations of weather in Ethiopia have been of recent origin, though there were many instances of references to extreme weather and climatic events in the history of Ethiopia as described by the chroniclers of the Ethiopian kings.

Early observations of weather in Ethiopia can be ascribed to the famous James Bruce, who came to Ethiopia to find the source of the Nile. He took rainfall observations from March 1768 to September 1773 AD in Gonder and from February 1771 to September 1771 AD at Qusquam (the location of the Empress Mentwab Palace).

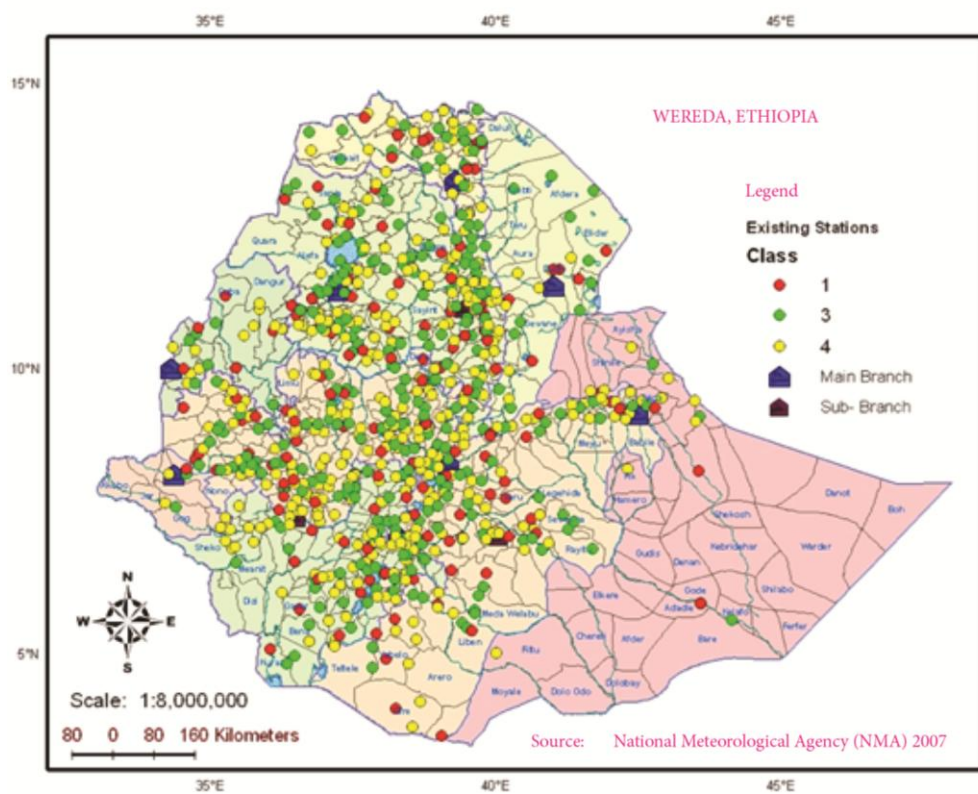
The first systematic meteorological observation started with the advent of the missionaries towards the end of the 19th century, with the instalment of two weather stations at Addame Tuluin 1890 and Gambella in 1895. During the short lived Italian occupation, and towards the end of the Second World War, about 192 meteorological stations had been installed in the country, mostly for recording precipitation (Fantoli 1965). The importance of meteorological services was first recognized in the aviation sector. Therefore, starting from the early 1950s, systematic weather observations, analyses and forecasting in Ethiopia became a routine process. The meteorological services were under the then Civil Aviation Authority.

The need for meteorological data, information and advisories for various development purposes and also the occurrence of drought in the 1970s necessitated the establishment of the

National Meteorological Agency (NMA) in 1980 by the government. Since the establishment of NMA, the status of meteorological services has significantly improved.

Currently, there are about 1150 meteorological stations (Figure 6.4 and Figure 6.5), which includes both the precipitation stations, third class stations, first class indicative stations and synoptic stations. Figure 6.4 shows the meteorological station network as of 2009. The significant increase in meteorological station coverage has been achieved through the meteorological station network master plan of NMA. The major weakness in the meteorological station network, however, is that the stations are concentrated along the roads and also in the highlands. A brief description of the NMA operation systems are described below.

Figure 6.4. Existing meteorological stations by 2009



Source: NMA 2007

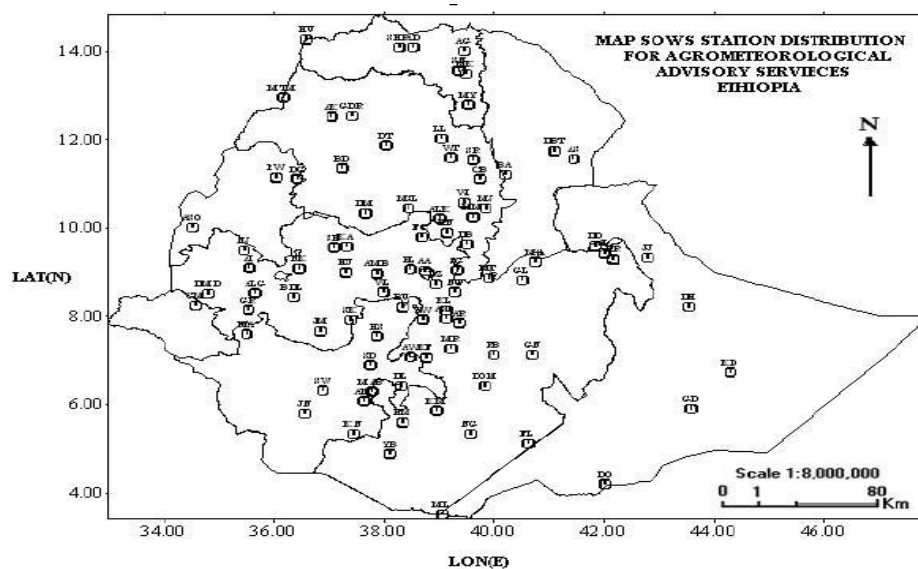
1. Remote sensing observation system

NMA receives remote sensing data from Meteosat second generation satellites every 15 minutes, and these data are processed and analysed to be used for weather forecasts and also agrometeorological assessments and forecasts.

2. Data collection and communication system

This includes data collection through the postal system and during station inspection for the third and fourth class stations and Single Side Band Radio/Voice telephone, for the near real time reporting stations which are used for early warning, forecasts and agrometeorological advisories. There are about 150 real time reporting meteorological stations used for this purpose. Daily rainfall, maximum and minimum temperature, relative humidity, wind speed and sunshine duration data are used from these stations for crop monitoring through the use of crop water balance. Figure 6.5 shows the location of the near real time reporting stations.

Figure 6.5. Near real time operational stations



Source: NMA 2009

3. Automatic weather stations

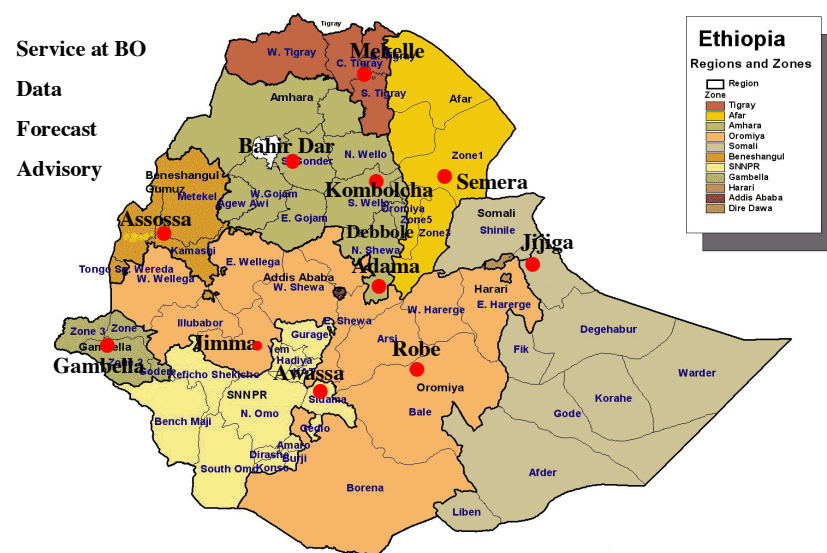
NMA in collaboration with WFP has installed 20 Adcon automatic weather stations in agropastoral areas of the country which are used for collecting meteorological data via GPRS to the national data server at NMA every 15 minutes. Additional installation of 15 Adcon automatic weather stations over different parts of the country is in progress and NMA is also considering further automation of its first class stations. The use of these Adcon automatic weather stations in agrometeorological advisories is considered to be of great potential as they can be used to monitor plant diseases by taking observations of leaf wetness for example.

4. Decentralization

The major differences in the agroclimatic characteristics of the country and the differences in the seasonality of the rainfall over different parts of the country made it necessary to

decentralize meteorological services. Thus NMA has established 11 meteorological branch offices (Figure 6.6). There has been a steady improvement in the capacity of the meteorological branch offices with regard to giving meteorological services to the local people.

Figure 6.6. Distribution of meteorological offices



Source: NMA 2009

5. Meteorological database

NMA has been using the Cli-database at the headquarters for the management of the data, and Excel based data management system at the branch offices. The meteorological time series spans 50–100 years but is much shorter for the recently established stations. Rainfall data is available in a computerized form. Recently, with the support of FAO, the computerization of meteorological elements required for the computation of Reference Evapotranspiration for the first class stations has been finalized. The meteorological database for the whole country is available at the headquarters, and for local users the meteorological database is also available at meteorological branch offices. Long term, temporally homogeneous time series of quality-controlled climate data are of great importance in a number of applications that include:

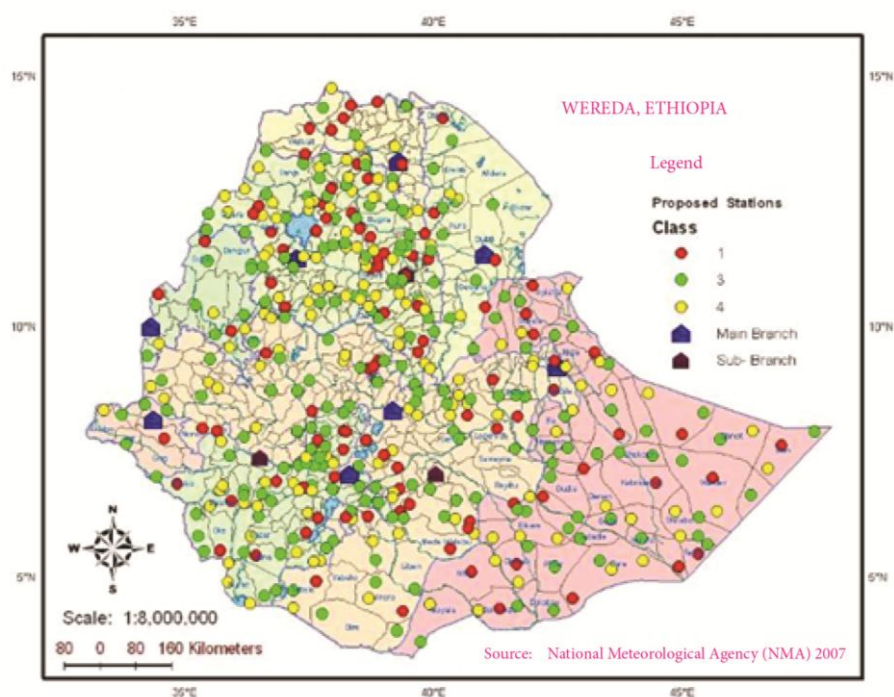
- Calibration of crop yield models and preparation of crop suitability maps;
- Characterization of climate risks over different locations;
- Planning and optimizing investments;
- Understanding trends, deriving statistics of interest, and placing current observations into historical context;

- Timely interventions for food security, flood and major climate sensitive diseases such as malaria;
- Designating and implementing weather index insurance; and
- Providing a basis for measuring and understanding climate change and variability

The weather stations are the conventional sources of climate data. Reliable climate information, particularly throughout rural areas of Ethiopia, however, is very limited. The available weather stations are unevenly distributed. The density of stations is relatively good over the central highlands, while lowland areas have very few stations. Almost all stations are located in cities and towns along the major roads. This imposes severe limitations to the availability of climate data to the rural community where, arguably, the data are needed most. For this reason, NMA has come up with a meteorological station network master plan in conformity with the WMO standards. Figure 6.7 shows the proposed stations to be installed by end of 2013.

Attempts to improve data services have recently started with the support of the International Research Institute (IRI) and the University of Reading. Improved data services include high quality spatial climatology with 30 years 10 daily grid rainfall data at 10 km resolution, 27 years rainfall satellite estimation (10 daily), 27 years combined satellite-gauge rainfall (10 daily), 30 years temperature grid data at 10 km resolution (10 daily), 10 years satellite temperature and merged station and satellite data (10 daily), with yearly updates. The outputs would be of high-resolution (10 km at 10 daily) grid databases that can be used to characterize observed recent climate variability and trends, climate change signals which can be used for verification of climate change projections. The grid data will include 30-year time series of rainfall data, satellite estimated rainfall merged with gauge-satellite rainfall, and grid minimum and maximum temperatures strengthened with satellite data (Figure 6.8).

Figure 6.7. Meteorological station network master plan



Source: NMA 2009

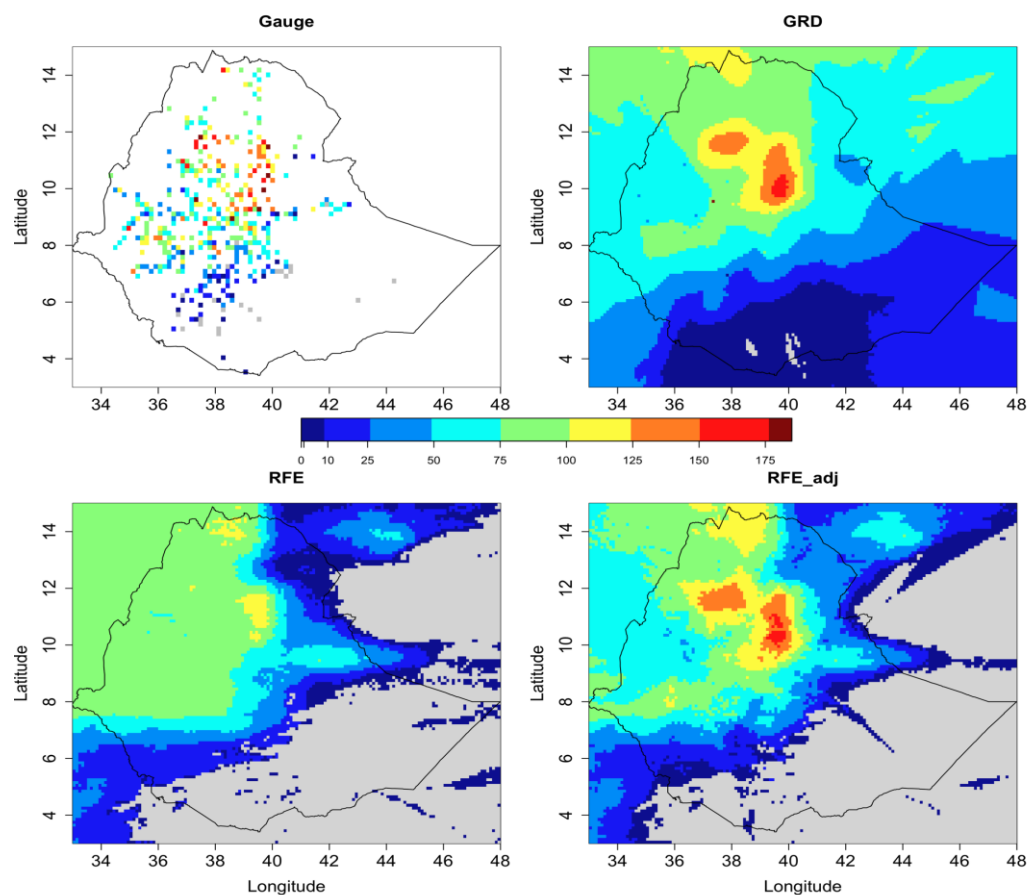
6. Weather and climate forecast and agrometeorological advisories

One of the objectives of the NMA is to provide weather forecast information for government agencies in civil aviation, agriculture and other weather dependent activities. NMA provides short term (1-3 days), medium-term (10 day), monthly, and seasonal forecasts. Maps are produced along with descriptive forecasts. The NMA forecasts indicate the amount of precipitation and are not designed to monitor soil moisture.

7. Short and medium term forecasts

The short and medium forecasts are based on numerical weather prediction outputs from the International Meteorological centres. Recently, NMA started running meso-scale NWP models (WRF and MM5) experimentally to give quantitative precipitation forecast for up to three days. There is also a plan under the new business process engineering of the agency for short-term forecasts to be issued by the meteorological branch offices to local users.

Figure 6.8. Gridding of rain-gauge and satellite rainfall estimate



Source: www.ethiomet.gov.et

8. Seasonal climate forecasts

Seasonal forecasts are important for the agricultural sector. Seasonal forecast by NMA is given at the beginning of every season: from June to September, October to January and February to May. It should be noted, however, that there is considerable spatial variation which highlights the importance of seasonal forecasts at the local level involving the meteorological branch offices. Seasonal forecasts in Ethiopia started in 1987. However, verifications at the local level indicate that substantial improvement in the seasonal forecasts issued for particular areas in the country is required (Getachew 2010). Currently, NMA is testing statistical and dynamical seasonal forecasting models on an experimental basis to improve the seasonal forecasts. Moreover, seasonal forecasting is accomplished by the National Climate Seasonal Outlook Forum, with the participation of the meteorological branch offices, which is crucial for downscaling of the seasonal forecast products to each region of the country.

9. Agrometeorological advisories

Agroclimatic and agro-ecological zonation of the country developed in the late 1980s by MoA in collaboration with NMA and FAO paved the way for the development of the agrometeorological information system. Agrometeorological services include advisories produced at the headquarters and also at the meteorological branch offices. Ten daily, monthly and seasonal agrometeorological bulletins are prepared and distributed to users and disseminated through the government media. Data used for the analysis of agrometeorological conditions consist of near real time meteorological and phenological data. Recently, the agrometeorology team started using a crop water balance computing software called LEAP (Livelihoods, Early Assessments and Protection), which was developed through the support of the WFP. The major products include:

- Ten daily, monthly and seasonal agrometeorological assessment and forecast;
- Crop water requirement satisfaction index;
- Agrometeorological advisories, especially during the crop growing season to be used as decision support tools.

The major gaps in agrometeorological services include challenges of reaching the agricultural community and also the inadequacy of agrometeorological software technologies and decision support tools (such as updated maps and tables for the country on agroclimatic, agro-ecological, soil water holding capacity).

Some of the major achievements through the years in agrometeorological services include the closer collaboration of NMA with the Directorate of Early Warning and Response of the MoA. Others include working actively with various governmental and non-governmental organizations in various task forces and participating in the national early warning working group and committee and also in field trips for crop assessment.

Recently, NMA has started an agrometeorology project that is designed to reach the farming community through the agricultural development agents. Currently, NMA is involved in a project supported by the WMO and funded by the Rockefeller Foundation with the following components:

- Establishment of climate and food security task force;
- Identify target districts;

- Training of trainers;
- Roving seminars involving farmers; and
- Distribution of plastic rain-gauges and training.

The pilot stage for this project is over and involved 14 sample districts (woredas) selected from all the regions of the country. It is expected that the scaling up of the project the whole country can improve delivery agrometeorological services at the community level.

6.3 Climate change implications for agrometeorological services

The impact of climate change and variability may be *ex ante* (before onset of the event) and *ex post* (after the event). *Ex ante* impacts are the opportunity costs associated with conservative strategies that farmers might employ to buffer themselves against climatic extremes at the expense of low average productivity and profitability, and inefficient resource use. This may include avoidance of improved production technology, selection of less risky but less profitable crops, or under-use of fertilizers. As a result, poor farmers may suffer from the impact of climate change and variability even in the years when climate conditions are favourable. On the other hand, *ex post* impacts are direct results of climate shocks such as droughts and floods. Effective agrometeorological advisories can play a significant role in improving farm level decision making.

Various consultations have been undertaken to assess the needs of users in the agricultural sector. Location specific forecasts (instead of forecasts covering large areas), accessing the necessary information in their locality, and getting the necessary knowledge on how to interpret or use the forecasts were among the needs identified.

Local level agrometeorological advisory services easily accessible to the farmers is one important option that can be used by the farmers, especially at the beginning of the cropping season. They can be used as to support decision making processes, to determine the planting time, and in the progress of the cropping season to be used for fertilizer application, weeding, and prevention of crop pests and plant diseases.

One of the most important aspects that a forecast must satisfy is that the forecast must be understood by the farmers. Majority of rural farmers do not have access to standard media channels such as radios, newspapers, television, internet, and e-mail. By the time the forecast gets to them, they would have already made their decisions based on traditional forecasting

knowledge. This requires a dissemination system which can reach the rural communities in timely manner.

However, problems of effective dissemination and communication exist in many rural areas of the country. One major problem is the use of technical terms that ordinary farmers do not understand. This hinders effective use of climate information in agriculture even though the media and other channels of communication of meteorological information are well established. Use of technical terms excludes the target audiences. Not many rural people understand probabilistic forecasts. Hence information targeted for the rural population should be prepared in local language and packaged in such a way that they can understand.

To effectively communicate, climate scientists ought to package climate information in ways that will be easy for farmers to understand. Information intended for farmers should be packaged differently from that for scientists. One option for effective dissemination is to communication of the forecast through the extension staff which is labour intensive and requires a great deal of resources for the extension staff to travel from one point to another meeting the farmers. In this regard, grassroot agrometeorological services can have a great impact. Useful agrometeorological advisories include advisories to the farmers that can help them in the decision-making process such as identifying the crop type, time of planting, and decision on what type of inputs to use. The best option for the farmers to get agrometeorological advisories will be if they can get it locally, either through the local agricultural development agent or through the meteorological personnel at a meteorological station level. Thus the meteorological stations will not only be for data collection but they can also become locations where farmers can come and discuss the weather and forecasts with the observer at the station.

Our current knowledge of climate change in Ethiopia largely depends on global and regional models. Though there is general agreement on the rate of warming, results from the different models regarding rainfall projections for different parts of Ethiopia are still inconclusive.

Although there is a general agreement on the projection of increase of the amount of annual rainfall, the implication for the agricultural sector may not be conclusive as long as we do not have the climate change projection of the rainfall on a seasonal and monthly basis for specific areas because agricultural production does not only depend on the amount of rainfall but also on temporal distribution of the rainfall. There is need to develop local area models with great

skill that can bring more certainty to the expected climate change scenario at the local level to identify the best local adaptation options.

Climate change studies are very important for developing local level adaptation options. NMA is currently the IPCC focal point, whereas the Ethiopian Environmental Protection Authority is the UNFCCC focal point. In general, climate change models suggest that climate will become more variable in Ethiopia, with an increase in occurrences of extreme weather events, making adaptation extremely necessary.

There is general agreement among the models that the autumn rainfall will increase. Some models, however, have shown a tendency for the February to May rainfall to decrease. These types of climate change downscaling exercises have not been undertaken over the different parts of Ethiopia, an important shortcoming in climate change research in Ethiopia. The higher learning institutions, NMA and the Environmental Protection Agency should work in collaboration. There should be emphasis on climate change downscaling for representative locations across the country, and the increased knowledge on the climate change scenario at local levels can be used to develop local adaptation options.

6.4 Key points for developing adaptation and mitigation strategies

Development of agrometeorological extension service

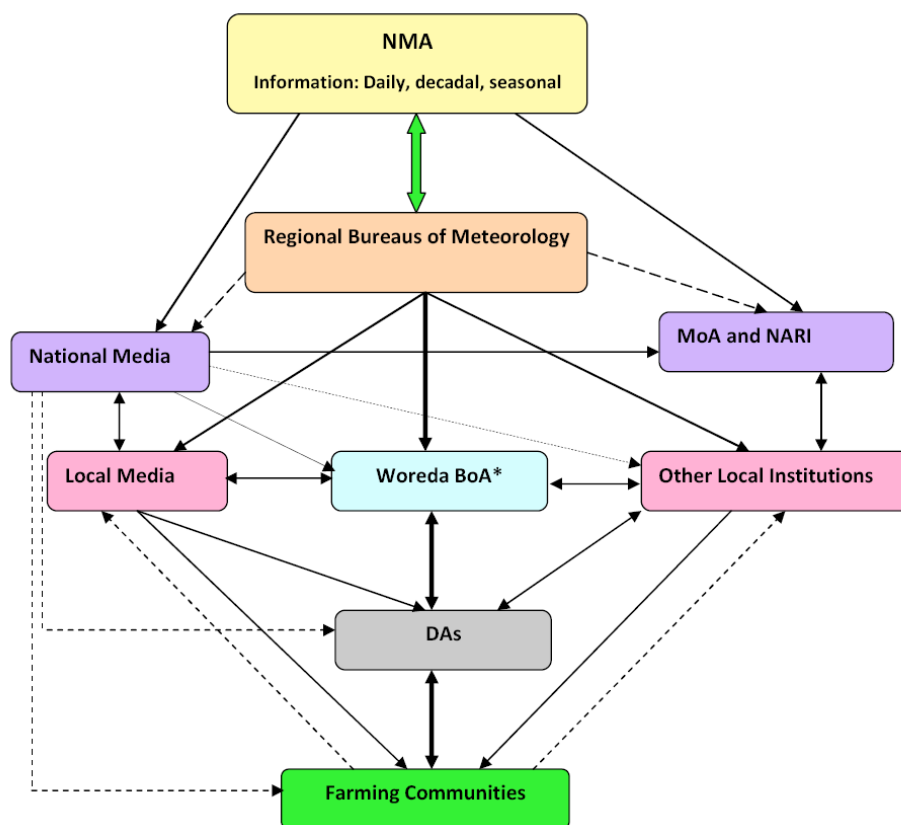
One major proposal regarding the different adaptation options to climate change has been improving weather and climate forecasts and use of agrometeorological advisories for the agricultural community as mentioned in the Ethiopian NAPA (NMA 2007). Key issues in the climate change adaptation process include how to use the agrometeorological information to cope with increased frequency of extreme weather events, the increased unreliability of rainfed agriculture especially over the semi-arid and the dry sub-humid parts of the country, survival of indigenous crops in a changing climate, and the problem of weeds, pests and crop diseases over many parts of the country, where wetter and warmer climates are expected.

Experiments conducted in the UK the “Food Chain Project supported by WMO among others, showed an increase of agricultural output by 25–35% on account of the use of climate prediction in the different stages of planning of agricultural practices. This is clear evidence that climate prediction can possibly influence agricultural production if used judiciously (Boodhoo 2003). Key issues in agrometeorological services in a developing country like

Ethiopia include i) how farmers can benefit from agrometeorological advisories as an adaptation option to reduce the high vulnerability of rain-fed agriculture to climate change; ii) how to address the knowledge gap on local level climate change trends and scenarios, so as to develop suitable adaptation and mitigation strategies; iii) how to address lack of awareness of decision makers at different levels and the society regarding climate change; iv) how to address lack of communication and coordination among the main actors involved in climate change.

This requires community targeted services that can reach the farmers, which contain weather and climate information that can be used by the farmers as a decision support tool for planting, weeding, fertilizer application, and control of plant pests and diseases. The best option would be to reach the farming community through the development agents. Figure 6.9 which was used for the Rift Valley region of Ethiopia (Getachew 2010), can be adopted for the whole country as a model of agrometeorological information dissemination through development agents.

Figure 6.9. A model for delivering climate information to farming communities and institutions involved in agriculture



*BoA = Bureau of Agriculture, DA= Development Agent, NMA = National Meteorology Agency, MoA= Ministry of Agriculture, NARI= National Agricultural Research Institute

Source: Getachew 2010

Community targeted advisory services

The success of climate change adaptation activities will only become real if there is active participation at the community level. Thus various types of advisory services targeting the community should be encouraged. Community level agrometeorological advisory will be realized with a series of training of trainers, woreda-level roving seminars with the participation of selected farmers, and the establishment of a woreda-level agrometeorological task force. A major part of the work would include dissemination of the short, medium and seasonal forecasts at the woreda level and also based on a tactical planning and fertilizing strategy as a means of reducing risk associated with crop production, using plastic rain-gauge observations at farm level. This strategy involves adjusting plant populations and nitrogen fertilizer inputs in “response” to the timing and amount of early season rainfall. Currently, NMA is undertaking woreda-level agrometeorological advisory for 14 selected woredas in the

country. Experience from this initiative can be scaled up across the whole country. Use of farm-level weather observation system based experiences in Mali can be very important in this regard. There has also been some activity in this regard by the NMA, where use of weather and climate data for the local area at farm level is demonstrated by adopting the Mali experience. Thus NMA has developed the plastic rain gauge mould and produced about two thousand plastic rain gauges and is also in the process of producing another 5,000 to enable farmers them at affordable prices. With appropriate training, it is expected that farmers will use the information to inform farm level decisions.

Capacity building in developing agrometeorological decision support tools

Availability of agrometeorological decision support tools for operational activities and development of agroclimatological decision support tools for medium and long term planning is another important aspect which can be used for planning of different agricultural activities. For example, how can we best address the long term feasibility of the cultivation of long cycle crops over the Rift Valley? These types of problems need collaborative efforts of agricultural sector and climate science sector professionals.

Capacity building in local area forecasts

Improvement of seasonal weather forecasts at local level must be considered as one important option that can be used as a decision support tool for determining the types of agricultural inputs for the farmer and also for strengthening the early warning system. Improvement of seasonal climate forecasts is indispensable for a country heavily dependent on rainfed agriculture as Ethiopia.

Capacity building in agrometeorological advisories for risk reduction and weather index insurance

Recently, insurance companies, donors and also the farming community have started getting involved in crop insurance. The Horn of Africa Risk Transfer for Adaptation (HARITA) is one such example. Weather crop insurance has been also mentioned as option for climate change adaptation in the Ethiopian NAPA. The major justification for index based weather insurance is that farmers may be encouraged to become bolder in taking risks by using more agricultural inputs and increase production. However, there are a lot of institutional, legal and capacity building issues that must be addressed for weather insurance to become beneficial for the agricultural sector.

Improvement of climate services for renewable energy sector

NMA undertakes meteorological observations which can be used as a good climate database for assessing wind and solar energy potential. Moreover, the improvement of operational forecasts regarding wind and sunshine duration can be useful with further development of the renewable energy sector.

Improvement of biometeorological service

Climate change has been associated with increased malaria epidemics, which usually occur when the threshold of rainfall, average and minimum temperature and relative humidity are conducive for the malaria vector. In Ethiopia, the malaria belt is expanding to the highlands with negative implications for the agricultural sector with regard to human labour, especially during crop harvest times when malaria epidemics are common and human labour is greatly needed.

Improvement of climate change research at the local level

Climate change research at the local level undoubtedly requires closer cooperation among the universities, meteorological services and research institutions in the country. Climate change downscaling requires a high capacity—in the form of powerful computers and trained manpower—and can only be realized if there is pooling of resources among different collaborators and stakeholders.

6.5 Conclusion

Climate change is a cross-cutting issue and thus requires close collaboration and coordination among various institutions and stakeholders in implementing climate change adaptation and mitigation interventions in any given vulnerable sector. In order to effectively deliver agrometeorological information to farming communities and to improve agricultural production, closer cooperation between NMA, MoA, regional agricultural bureaus, agricultural research institutes, and universities is necessary so as to improve the quality and format of agrometeorological information.

In order to improve knowledge and understanding of climate variability, trends and the downscaling of climate change projections and scenarios at local level, availability of trained human resources in climate change models, computing power capacity, and a high quality climate data set is required. Again, a closer collaboration between the Environmental

Protection Authority, NMA, research institutions, the universities and the Ministry of Education is necessary.

Development of agrometeorological and agroclimatological decision support tools can be realized through a closer collaboration between crop scientists, agrometeorologists, climate scientists and farmers as well. The identification of best crop cultivars, cropping patterns and also adaptation options to changing climate patterns requires the development of agrometeorological decision support tools, which can be applied for the different agro-ecological zones of the country. Facilitating these types of collaborations would first require capacity building of the major stakeholder institutions in climate change and may also require legislation and appropriate policies. There are many gray areas, where business as usual may present problems of conflict of mandates. In general, a review of legislation and policies should be undertaken and can be used to support climate and environment related activities.

References

- Boodhoo Y. 2003. *In Preparation for Climate Change*. In the Proceedings of the International Symposium on Climate Change, Beijing, World Meteorological Organization.
- Fantoli A. 1965. Contributo alla climatologia dell'etiopia, Ministero Deglia Affari Esteri, Cooperazione Scientifica e Tecnica. Rome. p. 558.
- Getachew H. 2010. *Analysis of Variability, Change and Climate Information Service for Crop Production in the Central Rift Valley, Ethiopia*. Haromaya University. M.Sc Thesis.
- Jember G. 2007. *Changes in the frequency and intensity of extremes over Northeast Africa*. M.Sc Thesis, Department of Meteorology, Wageningen University, Netherlands.
- Jember G, Tadege A. 2010. *Climate Change, Variability, Trends and Potential Impacts and Risks in Major Agro-Ecological Zones in Oromia region of Ethiopia*. In proceedings of strengthening, capacity for climate change adaptation in the Agricultural sector in East Africa. 5-6 July 2010, Nazareth, Rift Valley Hotel, Ethiopian Climate Change Forum.
- [NMA] National Meteorological Agency. 2007. National Adaptation Program of Ethiopia (NAPA). Final draft report, NMA, Addis Ababa.
- [NMA] National Meteorological Agency. 2009. Meteorological Station Network Master Plan Report. Unpublished.
- Obasi GOP. 2003. *The role of WMO and National Meteorological and Hydrological services in the field of Climate Change*. In the Proceedings of the International Symposium on Climate Change, Beijing. World Meteorological Organization.

7. Climate change and transboundary issues in East

Africa

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Abstract

Climate change contributes to conflicts in vulnerable areas such as across international borders. Increasing temperatures, rainfall variability and extreme weather conditions as a result of climate change will aggravate land degradation, deforestation and deterioration of freshwater. The impacts of climate change include shortages of food, water and other resources leading to human migration, environmental degradation and resource depletion and sometimes to violent conflicts. Climate change and resource scarcity are not the only cause of violent conflict, but threat multipliers that will in practice interact with other risk drivers, and with diverse sources of vulnerability. Reports show that about 46 countries, which are home to 2.7 billion people may experience a high risk of violent conflict as a result of climate change. Climate-induced water, energy and food stresses are critical challenges in the 21st century and require a comprehensive approach across all sectors and regions.

Increased global competition for resources will lead to increased international tension, which may spark violent, inter-state conflicts. Natural disasters and climate change have national security implications. Therefore, combating climate change should be a central policy of the 21st century. Poor governance of transboundary water resources often results in water conflicts, yet shared transboundary resources can also provide a basis for cooperation provided that threats are recognized and collaborative structures are put in place. Early warning and environmental risk assessment, structural measures to prevent conflict, reducing livelihoods vulnerability and promoting diversification, improving natural resource quality and quantity, strengthening natural resource management and participation, and conducting environmental diplomacy and mediation are some of the recommendations from this review.

Keywords

Climate change; transboundary; water resources; conflicts; East Africa.

7.1 Introduction

According to IPCC (2001), climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This includes environmental modification that occurs as a result of human activities that lead to the release of carbon dioxide into the earth's atmosphere from combustion of fossil fuels. Climate change has economic, social and security risks. Climate change affects a whole host of areas, including habitats, wildlife, terrestrial and aquatic ecosystems, and the associated goods and services, and livelihoods, which depend on these natural resources (Barnett 2003 in Islam 2009). The degree to which societies will experience the negative environmental and socioeconomic effects of climate change depends in large part on their vulnerability (ICG 2007). This can be measured by looking at (i) the extent to which societies are directly dependent on natural resources and ecosystem services, (ii) the extent to which the resources and services that societies do rely on are sensitive to changes in climate, and (iii) the capacity of societies to adapt to changes in these resources and services. Thus, while the environmental and socioeconomic effects of climate change are projected to be widespread, they will not be uniformly distributed because of varying levels of vulnerability.

Water shortages in international rivers cause conflicts and perhaps war. Thus, helping to end the water problems may reduce the possibility of conflicts. Water related wars are set to increase as water levels decline and rapidly growing populations increase pressure on water supplies. Schwartz and Randall (2003) noted that with over 200 river basins touching multiple nations, conflicts over access to water for drinking, irrigation, and transportation can be expected. Climate change has been significantly contributing to environmental degradation leading to human migration and violent conflicts (Kolmannskog 2008). About 46 countries, home to 2.7 billion people would experience a high risk of violent conflicts as a result of climate change interacting with economic, social and political problems (Evans 2010). Scarce of resources prompted by climate change may lead to conflicts. Climate change reduces availability of natural resources and provokes increased competition for these resources. Food, water and energy are resources of greatest concern.

Climate change may cause declines in food production, degradation of freshwaters, increases in storms and flood disasters and environmentally-induced migration. It is likely to intensify droughts, storms and floods, which may lead to environmental migrations and potential

conflicts in areas receiving migrants. Regions that exhibit more environmental problems and depend more heavily on the environment for livelihood also exhibit more environmental migration episodes (Reuveny 2007).

7.2 Objectives of transboundary cooperation

Transboundary natural resource management has a range of objectives:

- Conservation of biodiversity, ecosystem services, natural and cultural values across boundaries;
- Promoting landscape-level ecosystem management;
- Peace building and laying the foundations for collaboration (trust, reconciliation and cooperation);
- Increasing the benefits of conservation to communities on both sides of the borders;
- Economic development to local, national and regional economies; and
- Cross border control of problems such as security, fire, pests, poaching, pollution and smuggling.

7.3 Review of current situation and trends related to transboundary resources

7.3.1 Climate change-induced conflict over transboundary water resources

Transboundary water resources are those that cross one or more international borders. Climate change alters precipitation and the availability of water. Consequently, freshwater resources often shared across borders will be heavily affected. Transboundary waterways may become flash points where rainfall decreases and runoff becomes more variable (ADF 2010). Interstate tensions may arise from competition for limited water resources.

Large portions of major freshwater basins in the world fall within the jurisdiction of more than one nation (Uitto and Duda 2002). There are 263 rivers around the world that cross the boundaries of two or more nations, and an untold number of international groundwater aquifers. In their review, Wolf et al. (1999) found that 19% of these international river basins are shared by five or more states. The basin areas that contribute to these rivers comprise

approximately 47% of the land surface of the earth, support 40% of the world's population, and contribute almost 60% of freshwater flow (Wolf et al. 1999).

About 90% of Africa's freshwater resources are in river basins shared between two or more countries with competing national interests and limited mechanisms for cooperation or adaptation (Goulden et al. 2008). Over 80% of the land area of sub-Saharan Africa is located in transboundary watersheds, with over 50 international river basins (Uitto and Duda 2002).

When a major river flows through an arid region, there is a heightened risk of interstate conflict between upstream and downstream countries. Countries upstream have incentives to hoard water as a scarce and valuable resource, while downstream countries have incentives to enforce their will on weaker neighbours. Using these criteria, the Nile, Tigris, Euphrates, Mekong, and the Indus rivers are areas of potential conflicts. The economic and cultural destinies of approximately 300 million people are bound to the Nile River and its tributaries, from Central and East Africa to the Mediterranean Sea (Tadesse 2009). Tadesse's report further elaborates that because of the competing interest over the water, the Nile River has long been a source of conflicts. Climate change poses complex risks for the economies of Nile riparian countries as the warming of the earth's atmosphere will increase evaporation rates and crop water requirements, changing precipitation rates and reducing agricultural yields (Beyene and Negash 2009).

Zeitoun and Warner (2007) used the concept of 'hydro-hegemony' to analyze how countries exploit power inequalities to stake their claims to water resources. Hydro-hegemony is best described as somewhere between positive regional leadership that emphasizes cooperation, and regional dominance. Israel, Egypt and Turkey have established situations of dominant hegemony over the Jordan, Nile, and Tigris and Euphrates river basins, respectively (Zeitoun and Warner 2006). These countries are reported to have denied weaker countries their water rights, leading to low-intensity conflicts. These stronger countries control water resources through:

- *Resource capture:* Countries acquire or annex land or construct large-scale hydraulic works on rivers (for example Turkey's GAP project and Egypt's High Aswan Dam).
- *Containment:* Stronger countries dominate competitors, for example, by threatening economic sanctions, political isolation, or unevenly balanced treaties. Examples include the 1994 Israel-Jordan and 1959 Egypt-Sudan treaties.

- *Integration:* Some countries encourage more shared control of water resources, for example, South Africa's approach to the Orange River.

Climate change may cause reduction in water volume and pollution of water bodies. A gradual decreasing of water quantity or quality, or both, over time can affect the internal stability of a nation or region, and act as an irritant between ethnic groups, water sectors, or states/provinces (Wolf 2006). The resulting instability may have international effects. The pressures on water resources development leads to intense political pressures. Furthermore, water ignores political boundaries, evades institutional classification, and eludes legal generalizations. Water demands are increasing, groundwater levels are dropping, surface-water supplies are increasingly contaminated, and delivery and treatment infrastructure is aging. Collectively, these challenges provide compelling arguments for considering the security implications of water resources management. Surface and groundwater that cross international boundaries present increased challenges to regional stability because hydrologic needs can often be overwhelmed by political considerations.

Given the scope of the problems and the resources available to address them, avoiding water conflict is vital (Wolf 2006). Conflicts are expensive, disruptive, and interfere with efforts to relieve human suffering, reduce environmental degradation, and achieve economic growth. Developing the capacity to monitor, predict, and pre-empt transboundary water conflicts, particularly in developing countries is key to promoting human and environmental security in international river basins (Wolf 2006). In their endeavour to minimize the negative impacts of climate change and violent conflicts, cross-border cooperation will be very important. Governments should put in place holistic policy frameworks and adequate implementation mechanisms.

Global climate change affects rainfall patterns exacerbating periodic and chronic water shortages particularly in arid and semi-arid areas. International water utilization regulations (the Helsinki Rules) state that transboundary water has to be shared equitably and reasonably among riparian countries. To effectively implement such regulations, there is need for coordination and collaboration among riparian countries.

7.3.2 Climate change-induced food crises

Climate change will have adverse consequences for livelihoods, public health, food security, and water availability. Changing environmental conditions threaten to significantly reduce agricultural food production resulting in food crisis. Changes in temperature and rainfall would adversely affect cereal production in Africa and Asia. The linkage between water and food security in the Nile River basin, for example, is obvious as water scarcity impacts negatively on agriculture and therefore on food security. Agriculture accounts for half of gross domestic product (GDP) of the Nile River upper riparian states, more than 80% of their exports, and over 70% of their total employment (Tadesse 2009).

Climate change causes water scarcity. Water scarcity is probably the single biggest threat to food security anywhere in the world (Kindiki 2009). Impacts of climate change on African countries are severe because most African countries depend on rainfed agriculture and have limited capacity for climate change adaptation and mitigation.

In 2011 alone, climate change caused environmental and social crises in the Greater Horn of Africa. The whole of East Africa was hit by drought that was reported to be the worst in 60 years (IRC 2011). The IRC report further indicated that consecutive seasons of poor rains led to widespread loss of livestock and livelihoods, failed crops and soaring food prices, resulting in more than 10 million people facing a severe food crisis. As a result of the drought, the lives of millions of Somalis were at risk of hunger and disease. Similarly, thousands of people in northern Kenya and southern and southeastern Ethiopia faced severe food shortages with reported cases of loss of life (IRC 2011). Thousands of Somali refugees were reported to have crossed the borders into Ethiopia and Kenya.

Climate change poses serious challenges for water resources management (Beyene and Negash 2009). Energy supplies will undergo different changes as some nations seek to reduce emissions and current energy generating systems such as hydropower impacted by climate change. These changes, combined with increased competition for traditional energy resources, have the potential to cause inter- and intrastate conflicts.

7.3.3 Impact of climate change on pastoralism

Most of the key impacts of climate change will result from reduced freshwater availability, which will expose hundreds of millions of people to additional water stress (Evans 2010).

Decreased crop yields will expose tens to hundreds of millions of people to the risk of hunger. These are considered direct impacts of climate change. While poor people are undoubtedly vulnerable to the direct impacts of climate change, the most far-reaching effects of global warming may be the indirect consequences such as political instability, economic weakness, food insecurity or large-scale migration (Evans 2010)

Pastoral communities along borders are mostly insecure and this could worsen with increased climate variability (ADF 2010). Therefore, climate change and the livelihoods of pastoralists are interlinked. Climate change severely affects the livelihood of pastoralists because they depend heavily on livestock, which in turn depends on forage and water. Variability in weather patterns as a result of climate change has major implications for pastoralist livelihoods and security. Pastoralists live in hostile and arid environments which are prone to frequent droughts. Low precipitation and high temperatures affect availability of forage and water supply for livestock.

Drought has a negative effect on pastoralists as it causes loss of livestock. Pastoralists depend heavily on their livestock for their livelihood. Drought periods are positively correlated with increased incidences of ethnic conflicts over stiff competition for water and pasture, which sometimes extends across borders (Doti 2010). Pastoral insecurity determines grazing areas because when insecurity is high, livestock herds tend to be concentrated in small secure grazing zones, while leaving large tracts of land unused. Furthermore, cattle raids among neighbouring communities increase during droughts. Government security forces are inadequate or absent in most pastoral areas owing to their vastness and remoteness. As a result, most pastoralists acquire illegal arms for self-protection, hence aggravating the problems of proliferation of small arms and light weapons and creating an environment conducive for criminals to engage in commercialised livestock raids. The effects of climate change and its impact on pastoral communities are now more conspicuous than ever with evidence pointing to increasing levels of migration and conflicts over scarce resources (ADF 2010).

Doti (2010) further pointed out that there is limited presence of government officials and forces in the pastoral areas of northern Kenya, which has experienced conflicts for a long period. Therefore, the Borana pastoralists have to rely on their own defence system to protect their livestock from external aggressors by acquiring weapons to match those of their

adversaries which are easily obtainable through the porous borders of Kenya, Uganda, Ethiopia, Sudan and Somalia. Availability of small arms and light weapons has continued to create a desperate situation of permanent insecurity in the pastoral areas as well as making raiding easier and much more dangerous. Climate change is likely to compound existing pressures on water, food, energy, and land, which if not carefully addressed may create new and accelerated paths to conflict (Abebe 2009).

7.3.4 Impact of climate change on human migration

According to IOM (2011), climate change is expected to trigger growing population movements within and across borders, due to increasing intensity of extreme weather events, sea level rise and acceleration of environmental degradation. This in turn will impact on human mobility, likely leading to a substantial rise in the scale of migration and displacement. Although there is little consensus among scholars regarding the direct effects of climate change and human vulnerability, climate induced disasters and environmental changes like floods, sea level rise, cyclones and others are the direct cause of human insecurity and vulnerabilities (Islam 2009). People can adapt to environmental problems caused by climate change by staying in place and doing nothing, staying in place and mitigating the problems, or leaving the affected areas (Reuveny 2007). Human migration as a result of climate change can be grouped into three types (McCormick et al. 2010):

- Within a country
- Across an international border – environmental destruction is a major driver of migration across international borders and such migration can often lead to intense political conflict and destabilization for both countries.
- Across large regions of the globe for example migration from North Africa and Middle East to Europe. The resulting shift in demographics can result in serious tensions along social, cultural, or religious lines, as evidenced by the 2005 civil unrest in France.

People facing environmental disasters have no choice but to leave the affected area. Impacts of climate change will be different across different regions (IPCC 2001). The larger the migration and the shorter the period over which it occurs, the harder it is to absorb the migrants, raising the likelihood of conflicts. These problems may include threats, beating, appropriation, insurgency, skirmishes, and interstate or intrastate wars.

Climate change represents the ultimate resource scarcity perspective and may be a source of conflicts as increasing temperatures, precipitation anomalies and extreme weather is expected to aggravate situations in areas already experiencing high population pressure and resource scarcity (Urdal 2008). These factors may force millions of people to migrate, leading to increased risks of interethnic tensions and higher pressures on resources in destination areas. Environmental problems such as extreme weather events (frequent storms, floods, and droughts), land degradation, and declining freshwater resources play a role in migration (Reuveny 2007). Unlike economic and social factors, climate change and environmental degradation were rarely considered as important determinants of human mobility and migration in Africa (ADF 2010). Therefore, climate change did not feature at all in migration and development policies and plans in the continent. Global estimates suggest that as many as 200 million people could become climate migrants by 2050, doubling the migrant levels (ADF 2010). For example, 12–17 million Bangladeshis moved to India as a result of extreme weather events (Reuveny 2007). Environmental migration is pushed by several environmental factors acting concurrently. Land degradation, droughts, deforestation, water scarcity, floods, storms and famines are major environmental factors that cause environmental migrations. Such climate change-induced migration can promote conflict in areas receiving migrants. Competition, ethnic tension, distrusts and fault lines are the four channels that may lead climate change-induced migration to conflicts (Reuveny 2007).

Competition

Ethiopia shares borders with Kenya, Sudan, Somalia, Eritrea and Djibouti and almost all borders are in arid and semi-arid areas. As a result natural resources required for human and livestock survival are limited across these borders. The arrival of environmental migrants on either side of the border puts additional burden on the economic and resource base of the receiving area, prompting native inhabitants to compete over resources. Pressures are expected to rise with the number of migrants and residents, particularly when resources are scarce in the receiving area. The excess demand for resources may also generate lateral pressure, expansion of economic and political activities beyond the region's or state's borders in order to acquire resources, which increases the risk of conflicts.

Ethnic tension

When environmental migrants and residents belong to different ethnic groups, migration may promote tension because residents may feel threatened (Reuveny 2007). Sometimes host countries may fear separatism and migrants may attempt to reunify with their home country while residents may respond aggressively. Such ethnic disputes between migrants and residents can easily lead to conflicts.

Distrust

Transboundary movement of people from one country to another may generate distrust between the migrants and the hosts. For example, the migrants' origin country may suspect that the receiving country accepts migrants in order to show support for opposition groups of the other country or to weaken the political and military strength of the neighbouring country. The receiving government may suspect that the other government is interfering with its internal politics.

Fault lines

The conflict may also follow existing socioeconomic fault lines. For example, migrant pastoralists and resident farmers may compete over land, or migrants and residents may compete over jobs. Rebels may mobilize poor and frustrated rural migrants to challenge the state, which may respond with force.

Natural resources are scarce in most East African countries. Local communities along the borders of these countries are dependent on these scarce resources for their survival.

Therefore movement from one country to another along these borders will raise a concern and in some cases may result in conflicts. Environmental migrants may cause political instability and civil strife in the receiving area and also increase the likelihood of conflict as the migrants may join antagonizing groups or intensify the violence.

Climate change-induced migration may lead to conflicts in receiving areas and examples of such case are reported in a review by Reuveny (2007): (i) the arrival of Bangladeshi environmental migrants in India led to violence in the 1980s; (ii) tensions between internal migrants and residents in Bangladesh turned into an insurgency in the 1980s and 1990s; (iii) the arrival of environmental migrants from El Salvador in Honduras eventually led to a war in 1969 between the two countries; (iv) various interstate conflicts have been as a result of migration (El Salvador–Honduras, Ethiopia–Somalia, Mauritania–Senegal). Out of the 38

cases of migration directly attributable to climate change during the 20th century, half of these led to conflicts some of which were violent (Reuveny 2007).

Table 7.1 shows that environmental migration crosses international borders at times plays a significant role in conflicts. Environmental migration does not always lead to conflicts, but when it does, the conflicts intensity can be very high, including interstate and intrastate wars.

Climate change has been causing socioeconomic losses. Increased rainfall, for example, might increase the rate of soil erosion and leaching which has a detrimental effect on agriculture.

Similarly, drought might result in crop failure and death of livestock in pastoral systems.

These impacts on agricultural resources would in turn affect the social and economic circumstances of farmers and other socioeconomic sectors dependent upon their production.

Effects of climate change will be costly if mitigation efforts are not put in place. Mitigation, however, is certainly very costly. Faced with this kind of situation, one may take a “wait and see” approach, or act sooner, assuming that the costs of not acting will escalate. Practical action should be taken as soon as possible to minimize climate change-induced migration and conflicts. Climate change in developing countries may create a favourable environment for recruiting global terrorists. Climate change will aggravate existing problems of poverty, social tensions and environmental degradation. These problems threaten national stability of affected countries. People are likely to flee destabilized countries, and some may turn to terrorism. It is believed that the conditions exacerbated by the effects of climate change could increase the pool of potential recruits into terrorist activity.

Table 7.1. Episodes of environmental migration

Origin, period	Destination	Environmental push factors	Other push factors	Number of people migrating	Conflict in destination	Intensity of conflict
Bangladesh, various regions 1950s–current	India, West Bengal, Assam, Tripura	Droughts, water, land, food scarcity, land erosion, storms, salt intrusion	India’s diversion of Ganges River, failure to share river water, overpopulation	12–17 million	Hindu-Muslim violence, massacre	High
El Salvador, 1950s–1980s	Honduras up to the late 1960s, then US	Deforestation, land degradation, arable land or water scarcity	Wealth disparity, skewed land-tenure, poverty, overpopulation, repression	300,000 to Honduras, 500,000 to US	Migrant -resident resource contest, border dispute, 1969 Soccer War	Very High
Ethiopia/Eritrea, 1960s–1980s	Southern Sudan	Droughts, famines	Underdevelopment, Eritrean secession, war	1.1 million	Migrant-resident clash over water and land	Medium
Mauritania, 1980s–1990s	Senegal, Senegal River Valley	Drought, soil erosion, desertification, deforestation, water scarcity	Moors-African enmity, interstate war, Senegal river dam raises land values and stakes, population growth	69,000	Border skirmishes, ethno-religious violence, riots	High
Somalia, Late 1970s	Somalia-Ethiopia border region, Ogaden	Arable or grazing land degradation, water scarcity	Underdevelopment, population growth, interstate war	400,000	Migrant-resident water conflict, long-standing hostility	Medium
Ethiopia, Late 1970s	Ethiopia-Somalia border region, Ogaden	Grazing or arable land degradation, deforestation	Overpopulation, Ogaden war, land disparity, underdevelopment	450,000	Ethiopia-Somalia water and border dispute, resource competition, war	Very high
Somalia, Late 1980s–mid 1990s	Somalia-Ogaden, Kenya, Ethiopia, Djibouti	Drought, erosion, deforestation	Civil war in Somalia, population growth, overgrazing	2.8 million		Non-conflict

Source: Reuveny 2007

7.4 The need for institutions to manage transboundary resources in the face of climate change

According to Goldenman (1990) cited in Cooley et al. (2009), one of the major challenges ahead for the international community is to develop the principles, procedures, and institutions for managing and protecting shared water resources. Adapting to climate change requires changes in the institutions and policies that have been put in place under international treaties. There should be a shared understanding of the potential impacts of climate change, and transboundary mechanisms need to be in place for the implementation of adaptation measures.

Transboundary watersheds traverse political and jurisdictional lines of riparian countries. Heterogeneous and sometimes conflicting national laws and regulatory frameworks of these countries make management of watersheds a major challenge. Because of the complex nature of these issues, transboundary water management often requires the creation of international guidelines or specific agreements between riparian states (Cooley et al. 2009). About 158 of the world's 263 international basins lack any type of cooperative management framework and only 106 basins have water management institutions (Evans 2010). This clearly shows the wide gap in establishing institutions that significantly contribute to fair utilization of water resources thereby ensuring transboundary cooperation for sustainable development. This shows an urgent need for strong regional cooperation in conservation and sustainable utilization of transboundary water resources. Therefore, it has been recommended that for the effective implementation of transboundary treaties and international agreements, institutions with broad scope, which include all riparian nations, and management and enforcement authority needs to be established.

The Nile Basin Initiative (NBI) is one such institution established in 1999. NBI is an intergovernmental organization with a vision of achieving sustainable socioeconomic development through dedicated equitable use and sustainable management and development of the shared water resources of the Nile River (NBI 2011). NBI member States include Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda.

Water scarcity is the primary water management challenge in the Nile River Basin (Cooley et al. 2009). NBI provides an institutional mechanism, a shared vision, and a set of agreed policy

guidelines to provide a basin-wide framework for cooperative action. The policy guidelines define the following as the primary objectives of the initiative:

- To develop the Nile Basin water resources in a sustainable and equitable way to ensure prosperity, security, and peace for all its people;
- To ensure efficient water management and optimal use of the resources;
- To ensure cooperation and joint action between the riparian countries, seeking win-win gains;
- To reduce poverty and promote economic integration; and
- To ensure that the programme results in a move from planning to action.

NBI seeks to develop the river in a cooperative manner, share substantial socioeconomic benefits, and promote regional peace and security (Cooley et al. 2009, NBI 2011). Jägerskog and Phillips 2006 cited in Cooley et al. (2009), mentioned that rather than focusing on re-allocating flows, NBI has worked on the concept of sharing the many benefits of water, including energy generation, industrial use, and navigation. The Nile is one of the rain-dominated rivers and changes in precipitation and evaporation are likely to be the primary driver for changes in runoff (Cooley et al. 2009). Cooley et al. (2009) further points out that transboundary cooperation can broaden the knowledge base, enlarge the range of measures available for prevention, preparedness and recovery, and help identify better and more cost-effective solutions.

7.5 The role of climate-induced natural resources scarcity in transboundary cooperation

Climate and environmental stress may play a role in promoting collaboration. Water is an important example. Uitto and Duda (2002) reported that instead of being zones of conflict, shared water resources can provide a basis for cooperation and benefit sharing provided that threats to the international waters are recognized and collaborative structures are put in place. Interstate dialogue prompted by diminished water supplies can build trust, institutionalize cooperation on a broader range of issues and create common regional identities (ICG 2007). Examples cited by ICG include:

- Water access between India and Pakistan has served as an important feature of conflict resolution negotiations;

- In Latin America, interdependence among countries sharing access to the Lempa River basin has been conducive to the development of regional institutional mechanisms to manage supply.

These examples offer some hope that we may be able to successfully resolve and prevent resource-based conflict if we begin to take the risk of environmental conflict seriously, and explore ways in which resources can bring groups and communities together rather than divide them.

In handling transboundary natural resources, there is a need to move from confrontation to cooperation. Environmental diplomacy for conflict prevention, conflict management and peace building should be a priority for all concerned stakeholders. Environmental diplomacy is defined as a set of efforts to promote dialogue and cooperation to manage common environmental problems and shared natural resources as a way to mediate conflict and to create more peaceful relations between parties in dispute.

7.6 The costs of non-cooperation over transboundary natural resources

History shows that water can catalyze dialogue and cooperation, even between contentious riparian countries. Non-cooperation costs primarily inefficient water management, leading to decreasing water quantity, quality, and environmental health. But political tensions can also be affected, leading to years or even decades of efficient, cooperative futures foregone.

In the absence of institutions for conflict resolution, cooperation projects can become a flashpoint, heightening tensions and regional instability, and requiring years or, more commonly, decades to resolve (Wolf 2006). The Indus treaty, for example, took 10 years of negotiations, the Ganges took 30 years, and the Jordan took 40 years (Wolf 2006).

Wolf (2006) further reports that a common indicator of water conflict in a non-cooperative setting is shifting political divisions which reflect new riparian relations. In a survey of fourteen river basin conflicts, Mandel (1992) cited in Wolf (2006), offers interesting insight relating to the issue at stake with the intensity of a water conflicts. Mandel suggests that issues which include a border dispute in conjunction with a water dispute, such as the Shatt al-Arab waterway between Iran and Iraq and the Rio Grande between USA and Mexico, can induce more severe conflicts than issues of water quality, such as the Colorado, Danube, and La Plata rivers. Likewise, conflicts triggered by human-initiated technological disruptions

such as dams and diversions (for example, the Euphrates, Ganges, Indus, and Nile), are more severe than those triggered by natural flooding, such as the Columbia and Senegal rivers.

The UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Convention), adopted in 1997 by the UN General Assembly, is one post-Rio accomplishment that specifically focuses on international transboundary water resources. The UN Convention codifies many of the principles deemed essential by the international community for the management of shared water resources, such as equitable and reasonable utilization of waters with specific attention to vital human needs; protection of the aquatic environment; and the promotion of cooperative management mechanisms. According to Wolf (2006) the best management is adaptive management, that is, the institution has mechanisms to adapt to changes and stresses, and to mitigate their impact on its sustainability.

7.7 Conclusions and recommendations

The four dimensions of security in the context of climate change are climate security, human security, economic security and energy security. The scarcity of natural resources is known to trigger competition for the meagre resources available among individuals and communities, and even institutions, thus affecting human security in African. Stability is essential for sustainable development and to ensure security. African countries in general and East African countries in particular need to improve governance through:

- Maintaining stability and security by ensuring broad-based development;
- Building a coalition for action through strengthened institutional architecture and regional cooperation to address conflict prevention and resolution; and
- Improving disaster preparedness to reduce impacts.

Therefore, the following are recommended as a result of this review:

- Political commitment in putting in place legal provisions for sustainable development of transboundary natural resources and implementing them is critical;
- Harmonization of international legal provisions on transboundary natural resources such as water with national legal provisions;
- Putting in place monitoring and enforcement mechanisms of international and national legal provisions;
- Strengthen transboundary collaboration based on clear objectives;

- Generate and make use of scientific information on ecological status and sectoral uses of transboundary water resources, with the aim of producing a science-based assessment of the key transboundary problems and their root causes;
- Raising awareness;
- Building capacity among different ministries within each country to address issues related to transboundary resources;
- Management of transboundary natural resources using ecosystem-based approaches;
- Governments and other actors should implement sustainable and effective intervention measures such as:
 - Developing appropriate drought cycle management strategies at every stage of the drought, including, for example, water trucking, fodder provision, livestock reduction and warning systems for herders;
 - Providing drought early warning systems and awareness campaigns; and
 - Providing adequate security in the pastoral areas and promoting peaceful ethnic coexistence, indigenous methods of resource sharing and conflict resolution in pastoral areas.

References

- Abebe, L. 2009. Natural resource conflicts in West Africa: The case of the Niger River Basin. In: Tadesse D, ed. *Climate change and transboundary water resource conflicts in Africa*. Workshop Report. 29–30 September 2009, Mombasa, Kenya.
- [ADF] African Development Forum. 2010. *Governance for Peace and Security in a Changing Climate*. Issues Paper #6. Seventh African Development Forum. Acting on Climate Change for Sustainable Development in Africa. United Nations Conference Centre. Addis Ababa, Ethiopia.
- Beyene T, Negash F. 2009. Role of government in preventing climate change-induced water resource conflicts: An Ethiopian perspective. In: Tadesse D, ed. *Climate change and transboundary water resource conflicts in Africa*. Workshop Report. 29–30 September 2009, Mombasa, Kenya.
- Cooley H, Christian-Smith J, Gleick PH, Allen L, Cohen M. 2009. *Understanding and reducing the risks of climate change for transboundary waters*. Oakland, California: Pacific Institute.
- Doti T. 2010. Climate variability, pastoralists' vulnerability and options: The case of the Borana of Northern Kenya. In: Mwiturubani DA, van Wyk JA, eds. *Climate Change and Natural Resources Conflicts in Africa*. Monograph 170. Institute of Security Studies.
- Evans A. 2010. *Resource scarcity, climate change and the risk of violent conflict*. Background Paper. Center on International Cooperation: New York University.
- Goulden M, Conway D, Persechino A. 2008. *Adaptation to climate change in international river basins in Africa: a review*. Tyndall Centre Working Paper 127.
- [ICG] International Crisis Group. 2007. Climate change and conflict. (Available from <http://www.crisisgroup.org/en/key-issues/climate-change-and-conflict.aspx>) (Accessed on 25 July 2011)
- [IOM] International Organization for Migration. 2011. Migration and Climate Change. (Available from <http://www.iom.int/jahia/Jahia/copenhagen-and-beyond>) (Accessed on 16 June 2011)
- [IPCC] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Impacts, Adaptations and Vulnerability*. Summary for policymakers.
- [IRC] International Rescue Committee. 2011. Millions in need of lifesaving aid as UN declares famine in Somalia. (Available from <http://www.rescue.org/press-releases/millions-need-life-saving-aid-un-declares-famine-somalia-11268>) (Accessed on 25 July 2011)
- Islam R. 2009. *Climate change induced disasters and gender dimensions: Perspective Bangladesh*. Peace and Conflict Monitor. University for Peace.

- Kindiki K. 2009. Water and food security in the Nile River Basin: Legislative, policy and institutional arrangements for cooperation. In: Tadesse D, ed. *Climate change and transboundary water resource conflicts in Africa*. Workshop Report. 29–30 September 2009, Mombasa, Kenya.
- Kolmannskog VO. 2008. *Future floods of refugees: A comment on climate change, conflict and forced migration*. Oslo: Norwegian Refugee Council.
- McCormick J, Burns F, Sauer A. 2010. *Climate change impacts and national security*. Issue Brief, Environment and Energy Study Institute. (Available from http://www.eesi.org/072810_climate_security) (Accessed on 25 July 2011)
- [NBI] Nile Basin Initiative. 2011. About the NBI. (Available from http://www.nilebasin.org/newsite/index.php?option=com_content&view=section&layout=blog&id=5&Itemid=68&lang=en) (Accessed on 25 September 2011)
- Reuveny R. 2007. Ecomigration and violent conflict: case studies and public policy implications. *Human Ecology* 36: 1–13.
- Schwartz P, Randall D. 2003. An abrupt climate change scenario and its implications for United States national security. (Available from <http://eesc.columbia.edu/courses/v1003/readings/Pentagon.pdf>) (Accessed 5 August 2013)
- Tadesse D. 2009. Review of early experiences, current challenges and opportunities among the Nile Basin riparian states. In: Tadesse D, ed. *Climate change and transboundary water resource conflicts in Africa*. Workshop Report. 29–30 September 2009, Mombasa, Kenya.
- Uitto JI, Duda AM. 2002. Management of transboundary water resources: lessons from international cooperation for conflict prevention. *The Geographical Journal* 168: 365–378.
- Urdal H. 2008. *Demographic aspects of climate change, environmental degradation and armed conflict*. United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development. Population Division, Department of Economic and Social Affairs. United Nations Secretariat, New York.
- Wolf A, Natharius J, Danielson J, Ward B, Pender J. 1999. International river basins of the world. *International Journal of Water Resources Development* 15: 387–427.
- Wolf AT. 2006. *Background paper: Conflict and cooperation over transboundary waters*. Human Development Report 2006. Human Development Report Office Occasional Paper.
- Zeitoun M, Warner J. 2007. Transboundary water conflicts in the Middle East and North Africa. id21 Natural Resources Highlights 4: Water. (Available from http://r4d.dfid.gov.uk/PDF/Outputs/IDS/id21Water_4.pdf) (Accessed 5 August 2013)

8. Transitions in pastoral practices and livelihoods under changing climate: The case of Borana pastoralists in Southern Ethiopia

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Abstract

This paper looks at climate change-induced changing livelihood patterns among the Borana pastoralists in southern Ethiopia. The Borana pastoral production system has been exposed to increased frequent and severe droughts resulting in huge numbers of livestock deaths. Anecdotal evidence and climate data from Borana suggests more erratic and declining rainfall amounts and increased temperatures, all natural indicators of a changing climate. These changes have made the Borana people more vulnerable to drought, eroding their livestock assets and diminishing their level of food security. The Borana have tried to adapt to changing climate using their knowledge, skills and resources, through some shifts in their livelihood patterns and production practices. Other adaptation strategies involve increased crop cultivation to complement income from livestock and keeping more browsers in their herd mix (such as camels) as browsers are more tolerant to drought compared to grazers. In addition, households are diversifying their incomes and assets outside of livestock to better manage risks of drought. New range management practices such as hay making and large enclosures have been introduced to stock fodder. The Borana's willingness to invest in their children's education has increased as a means to provide alternative livelihood opportunities for their children outside livestock which is under stress. The Borana need policy and strategy support that will facilitate their efforts to adapt to the changing climate either to continue as pastoralists or for positive livelihood transformation.

Keywords

Climate change; livelihood trend; pastoralism; Ethiopia.

8.1 Introduction

Ethiopia is endowed with varying agro-ecology that supports different forms of livelihood strategies. The dry lands located in the east, southeast, northeast, south and southwest constitute more than 60% of the country's land mass. These areas are home to millions of pastoralists and agropastoralists who make their living primarily out of livestock keeping.

Pastoralism is defined as a production system in which people generate economic, social and cultural utilities from livestock that are herded using forage and water availability as indicators to decide upon the timing of herd movements (Delespaux et al. 2008). Several researchers have documented that time-governed mobility of livestock is a necessary condition to pursue a sustainable pastoral livelihood strategy (Coppock 1994, Desta 1999, Elias 2009). A viable and sustainable pastoral system involves a natural resource management practice that maintains the ecological balance between pasture, livestock and people (Nori and Davies 2007 cited by Troeger 2011). This ecological balance requires mobility of livestock and/or herders as there is temporal and spatial variability in availability of pasture and water in arid and semi-arid ecosystems.

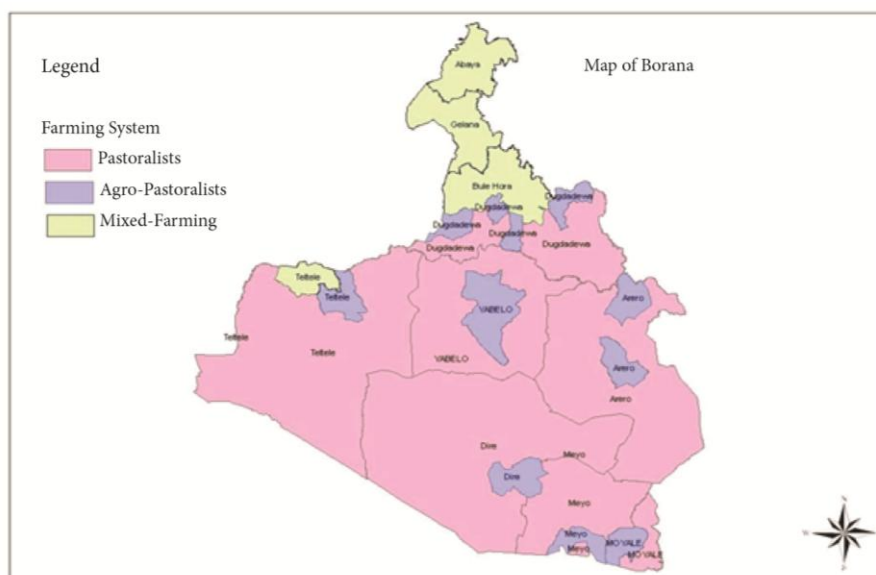
Pastoralists in Ethiopia raise diverse species and breeds of animals, each suited to a particular ecological niche including forage, water and minerals. The holding and management of multiple species of livestock with multiple functions along with mobility were the key strategies used by pastoralist for centuries to reduce risks related to diseases, forage, water, market, conflicts and climate variability and changes.

Pastoralism in Ethiopia has been surrounded by several stressors of different nature including environmental, political, social, and economical (Coppock 1994, Desta and Coppock 2002, 2004,; Troeger 2011, PFE 2011). Despite all these stress factors, the system maintained its basic feature of keeping livestock and survived for centuries, proving to be a dynamic system that adapts to various shocks including extreme weather events. But recently it has been faced with a new and serious challenge of climate change which is beyond the capacity of the pastoralists to cope with using the conventional traditional ways (Troeger 2011, PFE 2011, Desta and Coppock 2002, 2004). New ways are emerging and evolving to deal with the new problems associated with climate change.

8.2 Study area and methods

The study was carried out among the Borana pastoralists in southern Ethiopia (Figure 8.1). The southern Ethiopian rangeland is situated in a semi-arid to arid agro-ecological gradient. It has been one of the most important livestock producing areas in the Horn of Africa (Coppock 1994). This rangeland is primarily inhabited by the Borana ethnic group who are predominantly cattle keepers. There are also other minority groups in some pocket areas such as the Gabra who are mainly camel breeders. This rangeland has long been viewed as a typical savannah-type productive rangeland, well adapted to the delicate arid and semi-arid environments. The Borana traditional resource and livestock management practices and their governing institutions have also been effective and productive in managing the system. However, recently, similar to other pastoral systems in Ethiopia, the ability of the Borana pastoral system to support the livelihood of the herding population has diminished due to recurrent drought that destroys their livestock assets (Coppock 1994, Desta and Coppock 2002, 2004). Although drought is an inherent characteristic in arid systems, what the Borana pastoralists have seen in recent years has been very unusual. Frequency and severity of dry years and drought have increased which destroyed their livestock assets. This in turn led to increased poverty and diminished food security among the Borana pastoralists.

Figure 8.1. Map of study area



The paper is based on a desk review of previous studies in Borana by different researchers and institutions over the last 30 years. Results of research from previous studies as far back as 1985 were compared to results of recent studies as 2011 to understand livelihood changes and production practices that have occurred among the Borana pastoralists.

8.4 Results and discussion

8.4.1 Climate change and Borana pastoralists' perception

The Intergovernmental Panel on Climate Change (IPCC) refers to climate change as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC 2007). There are natural as well as human induced factors that have the potential to change the climate. There is a general consensus that climate change and global warming are real. However, the direction, magnitude and impact of the change in different regions and different ecosystems are uncertain. Studies indicate that global warming and increased climate variability will be more intense in Africa than in the rest of the world and will severely affect African agriculture and pastoralism more than any other sector (Njoya 2009, IPCC 2007, Isobel and Grahn 2007). Although not too certain, the general picture in African pastoral areas is one of increasing aridity resulting from decreasing amounts of rainfall and variability in the seasonal pattern. There is also an increase in temperature that will increase evaporation. Increases in aridity in the pastoral system affect the quantity and quality of pasture produced which in turn affects livestock productivity and food security of the herders.

Riche et al. (2009) studied the climate change in Borana and Shinile zones, looking at 30 year rainfall and temperature data (with some missing) for Mega, Moyale and Teltele rainfall stations in Borana. They found that rainfall has been decreasing and temperature increasing which is an indication of increasing in aridity in Borana. In a focus group discussion (FGD) conducted as part of the same study, pastoralists mentioned drought as the main climate-related hazard in both zones (Riche et al. 2009). According to the FGDs and other key informant (KI) respondents, frequency and severity of drought had increased in Borana and Shinile zones. They all agreed that while in the past drought used to occur in 6–8 year intervals, but now it is happening every other year. The opinions of the FGD and the KI have been consistent with the results from the climate data analysis from the three districts of Mega, Moyale and Teltele. The FGD and KI respondents also mentioned that the livestock

death after each drought was increasing. The FGD identified additional hazards that hit Borana to include resource-based conflicts, bush encroachment, livestock and human diseases, extreme heat, and land degradation. All these have some linkage with climate change (IPCC 2007). Similar results were reported in studies by the Pastoral Risk Management Project (PARIMA) in Borana. Pastoralists indicated that although drought is a common incident in the rangelands, it has become so frequent and too severe to bear its consequences (Coppock et al. 2008).

Results of another study by Elias (2009) in Borana were in agreement with the findings from the FGD and the KIs who said that the Borana area has become more arid and dry. Analysis of rainfall data (1977–2007) and temperature parameters by Elias (2009) for three stations (Yabello, Negelle and Moyale) in Borana revealed that the moving average of total annual rainfall was constantly declining in all sites but more pronounced in Negelle and Moyale. The daily mean minimum temperature showed a drastically increasing trend across all sites.

The perception and experiences of Borana elders about climate change and its manifestations were also in agreement with the above findings. Pastoral elders stated that they have been experiencing unusual climate changes that have resulted in severe and continuous droughts never seen before. According to the elders, rainfall has become highly variable and its spatial distribution unpredictable. As a result of the changes, rangeland degradation has become too visible in the area and ponds and other water facilities have dried up. A Borana elder who made an oral presentation at the 5th Annual Pastoral National Conference, “Climate Change and Pastoralism: The Implications on Sustainable Pastoral Development in Ethiopia” reiterated that climate change is real in Borana, and pastoralists are feeling the impact. He said,

“Climate change in Borana area is not something of the future alone. It is something of the past, the present and the future. It has been there with the pastoralists for the last 3–4 decades. It is now becoming more intense and has become full of surprises of extreme weather events. And the future will get worse unless immediate action is taken to reverse the trend. It has been a long time since the Borana pastoralists have realized the climate change and began to live with it. Normal rainfall regime and its distribution pattern in Borana have been distorted. Drought has become a recurrent occurrence and its severity has increased. We are surprised

with unpredictable flooding. The weather is getting unusually hotter; the seasonal rainfall is losing its pattern” (PFE 2011).

There is consistency between the scientific and the anecdotal evidence, all pointing toward the inescapable fact that climate change in Borana is real. Community members, government officials and non-governmental agencies and researchers who have worked in Borana for the last several decades have witnessed the change. The rainy seasons have become shorter as a result of late onset and early cessation, which decreased the length of plant growing period, and increasing temperatures that have led to aridity and desiccation. The severe droughts that occurred in the 1970s, 1980s, 1990s and the 2000s are adequate evidence to suggest that there is a permanent shift in climate in Borana.

8.4.2 Climate change impact

Pastoral areas of Ethiopia have experienced the impact of climate change for decades. According to the Borana pastoral elder who spoke at the pastoral national conference, he had this to say regarding the impact of climate change:

“Potential of the rangelands to support pastoralism in a sustainable manner has been reduced due to the deterioration of the climatic condition. Livestock are dying in hundreds of thousands after every drought. Pastoralists are becoming poorer and poorer as their basic livestock asset has been depleted and gradually moving towards other livelihood strategies including those which negatively affect the health of the natural resource, such as cutting trees for charcoal making which in turn speed up the rate at which the climate is changing. Opportunistic crop cultivation has expanded. Soil erosion and gully formations have become a serious problem. As resources in pastoral areas dwindled as a result of climate change, more pastoralists dropped out of the system, migrated to urban areas, and took economically inferior jobs. Climate change has caused and fuelled conflict as resources became too scarce and pastoralists lean more towards competition and conflict than cooperation and sharing. As poverty continues to increase the social safety nets and traditional insurance mechanisms founded on sharing and reciprocity have weakened and made the impact of climate change unbearable” (PFE 2011).

Findings of a study by Riche et al. (2009) in Borana and Shinile reported similar results to the opinion of the elder in many respects. According to the study, there was a sharp decline in

availability, productivity, and quality of pastures and farmlands and an increase in resource-based conflicts between different groups as they compete for shrinking and dwindling resource base. The study also found that the traditional asset redistribution and mutual assistance mechanisms that worked well for centuries have failed to support the poor households or those who lost their livestock assets due to drought, conflicts or diseases as more and more people were becoming needy and people with surplus to support others became less and less (Riche et al. 2009, PFE 2011, Desta and Coppock 2002, 2004).

8.4.3 Changing practices and livelihood strategies to adapt to climate change

Adaptation is the ability to respond and adjust to actual or potential impacts of changing climate conditions in ways that moderate harm or take advantage of positive opportunities (Oxfam 2007, Gebremichael and Kifle 2009). It reflects positive actions to change the frequency and/or intensity of impacts, as opposed to coping strategies that are responses to impacts once they occur.

Pastoralists in Ethiopia have tried to adapt to climate change as best as their capacity has permitted them. In some instances they have been forced to adapt to it, because they have no choice but to adapt their lifestyle to cope better with the change. The Borana have used their traditional livestock and resource management mechanisms such as mobility, diversification of livestock species, spatial and temporal herd dispersal, and social safety nets to adapt to climate variability and extreme weather events. However, with the steadily worsening climatic changes, the Borana have begun to do things slightly differently from what they used to do traditionally. In some cases they have modified the old methods to respond to the new situations and in others they have come up with new ones. New practices and a few of the old but modified practices and livelihood strategies employed by Borana pastoralists to adapt to increasing climate change are discussed in the following sections.

Crop cultivation

Three to four decades ago, it was unthinkable to see Borana pastoralists practicing farming widely in the rangelands (Legesse 1973). In the 1960s only a hand full of Borana pastoralists were cultivating regularly. Cultivation expanded in the Borana rangelands after the 1983–84 drought as pastoralists planted maize and beans to deal with food shortages created by massive cattle mortality, especially milking cows (Desta and Coppock 2004). Cultivation was

further promoted by the local government to support displaced and settled destitute pastoralists who lost their herd due to the drought (Desta et al. 2006). These people were settled in and around valley bottoms in the rangelands where soil moisture content was relatively higher and provided with seeds and farm tools to cultivate. As recently as the 1990s farming was regarded as a poor man's job and it was considered as an inferior form of livelihood strategy (Desta 1999). It was the poor and the stockless pastoralists who were deliberately cultivating to make a living. A few wealthy herders were cultivating but only to avoid sale of livestock to buy grains. As droughts have become more severe, the situation has also changed. A large number of Borana have begun cultivating mainly maize and beans which are the main food crops in the area.

Desta et al. (2004) documented that in the 1996/97 season, 67% of the 317 Borana surveyed were cultivating. Average land cultivated per household was less than 2 ha. In a recent household baseline survey by the research programme Climate Change, Agriculture and Food Security (CCAFS) in Yabello woreda, Borana zone, more than 93% of the 140 households surveyed were cultivating. The average accessible plot for cultivation per household was more than 1 ha, with a maximum of 5 ha (Desta et al. 2011). Although the likelihood of a successful harvest in the rangeland is less than 20%, the Borana have continued cultivation at an increasing rate. Even the wealthy pastoralists are now practicing farming widely to complement their income from livestock. They even hire tractors for land preparation (Desta *personal observation*).

In response to erratic and declining rainfall, pastoralists have begun to plant early maturing crops that require less moisture. Two-thirds of the 140 households surveyed in Borana have made changes in one or more of their important crops (Desta et al. 2011). The changes have been mainly from cereals to beans and from long to short maturing maize varieties. These changes were made due to a combination of climate change and market factors.

Farming has become a livelihood and food security strategy for a growing number of poor pastoralists. There has been speculation that it was the drop in per capita cattle holding that resulted from the frequent drought which drove Borana to engage in expanded crop cultivation. Desta and Coppock (2002, 2004) documented a drop in per capita cattle holding from 90 heads to 30 among the Borana pastoralists. It could even be lower now, given the repeated droughts that occurred recently, killing thousands of livestock. According to the

CCAFS household baseline survey (Desta et al. 2011), 80% of the respondent households had less than 20 heads of cattle, 13% had 21–50 heads and it was only less than 3% who had 51–100 and none had more than 100 heads.

Introduction of new livestock species

Traditionally Borana pastoralists are cattle keepers. The dual purpose Borana cattle are one of the best breeds that do well in the arid environment. Three decades ago very few Borana pastoralists used to keep camel. Coppock and Mamo (1985) in a survey of 60 Borana encampments encompassing some 1200 households estimated one camel for every 10 households, and the majority were male camels mainly kept for transportation purposes. Most Borana pastoralists were against keeping and breeding camels as they believed camels destroy the savannah grassland by stamping on the herbaceous layer and also by spreading bushes all over the rangeland through their dung after browsing on bushes (Kerarsa Guracha, Borana elder, *personal communication*). Drinking camel milk was also not common among the Borana. From a survey of 336 Borana households in 1996/7 there were about 1.7 camels per household (Desta and Coppock 2004). This suggests a major increase over a 12 year period compared to the findings of Coppock and Mamo (1985). Results from the CCAFS survey revealed that 38% of the 140 households surveyed own a minimum of 1 and a maximum of 20 camels on average (Desta et al. 2011). Now camels have become an important species for the Borana both to improve food security and to generate a higher income. A mature fat male camel can fetch up to US\$1200 compared to a mature fat male Borana bull which fetches not more than US\$300 in Moyale and Babile markets (Desta *personal observation*). In the same CCAFS survey, 82% of the 140 households had one or more goats. There has been a major shift in livestock species compositions held by the Borana in response to encroachment of woody vegetation that favours browsers and the increasing aridity of the environment. Camels and goats are considered by many Borana pastoralists to be more drought tolerant than cattle and sheep.

Economic diversification

Income and asset diversification is one of the best strategies in climate risk management (Desta 1999). Dependency on one source of income, e.g. livestock, was among the factors for pastoralists' vulnerability to shocks. Diversification could give pastoralists the option to manage risk better. In response to the changing climatic conditions and recurrent drought,

Borana pastoralists have been forced to diversify their asset and income holdings to cope with shocks and improve food security. Main diversification strategies commonly used by the Borana include crop cultivation, petty trading, livestock trading, collection and trading of non-timber forest products, bee keeping, charcoal making, sale of fuel wood, wage labour, mining, and house construction in towns. Desta and Coppock (2004) documented the increasing interest expressed by respondents in Borana to diversify their economy, given the increasing pressures on their livestock resources. Respondents believed that those pastoralists who diversified in particular into farming were better able to cope with drought and meet their food needs compared to those herders who relied on livestock only.

A recent household survey done in Borana found that 65% of the respondents were engaged in some form of petty trading (Elias 2009). Some richer pastoralists were engaged in informal trade of animals across the Ethiopia-Kenya borders. Trading in charcoal was also occasionally practiced by 14% of the pastoralists around major urban centres such as Yabello and Negelle (Elias 2009).

Recently, poultry production has become an important income generating activity for the pastoral Borana and is mainly for sale to town dwellers. In the past, Borana were unwilling to raise or consume chicken. Even now most do not consume chicken or eggs. However, recently those Borana living in close proximity to towns began raising poultry in large numbers. In the CCAFS household baseline survey, 56% of the respondents were found raising poultry for markets (Desta et al. 2011). This is a recent activity which was uncommon for a mobile or transhumant pastoral community.

Investment in children education

Following the 1996 “Gumi Gayo” resolution to enhance education for the youth, the Borana have shown huge interest in promoting education of their children. They have become more willing to send their children (both male and female) to school. The young men have also begun demanding of their parents for formal education in order to sustain their own future (Riche et al. 2009). In the face of frequent drought and huge livestock mortalities, the Borana pastoral economy could not continue as a viable livelihood strategy without a strong linkage to the urban economy, in which education was taken as the best vehicle to facilitate the linkages (Huqqa 1999).

In a survey of 317 Borana households in 1996/97 by Desta and Coppock (2004), it was found that only 57 households (18%) had members with any formal education within the household. The rate of illiteracy per capita was also 92% (Desta and Coppock 2004). In the CCAFS household baseline survey in Borana, it was found that 76% of the surveyed households had someone in the household who had obtained a primary, secondary, or post-secondary education (Desta et al. 2011). A quarter of the households had no members with formal education (Table 8.1).

Table 8.1. Highest level of education obtained by any household member

Highest level of education of any resident household member	Per cent of households (n=140)
No formal education	24
Primary	46
Secondary	16
Post-secondary	13
Total	100

Source: Desta et al. 2011

As indicated in Table 8.1, 29% of the households had members with secondary and post-secondary education. This high figure depicts the fact that Borana pastoralists are increasingly willing to invest in their children's higher education. The Borana now believe that education is one of the means for out-migration from an environmentally strained system. Moreover, it creates the opportunity for remittances. Education also enhances diversification. Households with members having formal education were positively associated with economic diversification outside of traditional livestock production (Desta and Coppock 2004).

Enclosures for dry season grazing and hay making

Keeping dry season enclosures was a common range management practice among the Borana to save pasture for calves, milking cows and weak animals during dry spells or drought (Coppock 1994). In the past, dry season enclosures used to be small in size and they were communally owned. They have never been owned privately. Hay making and stockpiling of fodder deliberately for dry season reserves were not common practices in Borana. Hay used to be harvested in small amounts by women to feed calves and sick or very weak animals which are kept at the homestead. Recently, the Borana have modified and scaled up some of their range management practices to deal with the increasing frequency and severity of drought. Enclosures are now built to serve large numbers of herders, more categories of livestock and

for longer periods of time. The practice has expanded into more areas in the southern rangelands. Pastoralists have begun preparing and stocking up hay for use in the dry seasons. These practices have been partly promoted by government and NGOs and partly by the communities themselves. Enclosures and hay making have grown in popularity and are practiced by an increasing number of Borana pastoralists to protect their livestock. According to the CCAFS household baseline survey, the Borana are still largely dependent on livestock for their livelihood (Desta et al. 2011). The large number of households involved in the production, consumption and marketing of livestock and livestock products, and the high production and consumption of fodder, signify the high livestock dependency of the Borana pastoral system. Hence such enclosures could contribute towards protection of Borana pastoral livelihoods. Pastoralists also make and stock up hay for dry and drought periods from grasses harvested from the enclosures. The interest among the pastoral communities in Borana to put aside more lands for enclosures and hay making is growing (Nicholson and Desta 2010). Borana pastoralists have begun buying and selling hay during critical dry periods. Pastoralists have even started to purchase and bulk hay from the highlands to feed and rescue their drought stricken livestock and also for resale to make money. Hay has never been a marketable product in Borana. This experience was largely widespread among Borana following the most recent drought episodes in 2006, 2008 and 2011 (Coppock et al. 2008, Atlaw *personal communication*).

8.5 Conclusions and recommendations

This paper demonstrates that climate change in the Borana pastoral area is real and has been affecting the pastoralists for decades. Anecdotal evidence and analysis of climate data reveals more erratic and declining rainfall amounts, while temperatures have increased. Climate change has negatively affected Borana pastoral livelihoods and increased their vulnerability to drought. Pastoralists are repeatedly losing their livestock assets resulting in increased food insecurity. Droughts have become more frequent occurring every 2–3 years if not every other year, denying the Borana pastoralists adequate time for herd recovery. At least 5–6 good years are required for a herd to recover.

The Borana pastoralists are increasingly using their own skills, knowledge and capacity to adapt to changing climate, demonstrating how capable they are in dealing with the problem, if given appropriate support. Having survived various climatic shocks of the 1960s, 1970s,

1980s, 1990s and the 2000s, using their own knowledge and capacity, implies that Borana pastoralists can adapt to climate change successfully if given the right enabling environment. In response to changing climate, Borana pastoralists are changing their livelihoods and production practices. More pastoralists are cultivating crops and introducing short season varieties that are tolerant to moisture stress and warmer environments. Herd composition is also changing from heavy grazer-dominated herds to more browsers to balance the change in vegetation composition and increasing aridity of the system. Other adaptation strategies include more protected and larger dry season enclosures, diversification into non-pastoral and non-agricultural income-generating activities (e.g. investing in housing, hotel, and transport businesses). Increasingly, more households are willing to invest in their children's education for future generations to be able to diversify their livelihood strategies.

The changes in livelihood strategies signal a gradual shift from traditional pastoralism to more market-oriented and diversified livelihoods driven by the need to attain food security in the face of climate change-induced droughts. The livelihood shift could be a positive transformation if enabling policy arrangements are put in place and key strategic support provided to enhance these local initiatives. There is need for policies that facilitate their engagement in other income-generating activities as they transition into a market economy. Policies that facilitate introduction and implementation of improved range management, water development and dry land farming technologies and practices that take into consideration climate change are urgently needed. Examples include scaling up of dry season enclosures, hay making, water development and conservation, access to early maturing and drought tolerant multipurpose crops and pasture varieties, bush and invasive species management, and tree planting. Protecting the pastoralists against the effects of climate change is directly linked to protecting and promoting mobility. Borana pastoralists' mode of production is based on mobility across geographically distributed wet and dry season grazing and watering units. It is important to develop policies that facilitate livestock mobility, especially as rainfall becomes increasingly erratic and unpredictable. Traditional institutions and networks founded on the principle of reciprocity are important forms of social capital in Borana pastoral systems that enhance sharing of resources and management of conflicts. Peaceful coexistence and cooperation between pastoralists facilitates efficient utilization of available resources that could contribute towards better adaptation to climate change.

References

- Coppock DL. 1994. The Borana plateau of southern Ethiopia: Synthesis of pastoral research, development and change, 1980-91. Systems Study No. 5. International Livestock Center for Africa (ILCA). Addis Ababa, Ethiopia.
- Coppock DL, Gebru G, Mesele S, Tezera S, Desta S. 2008. Are drought-related crashes in pastoral cattle herds predictable on the Borana plateau? Research Brief 08-02-PARIMA. Global Livestock Collaborative Research Support Program (GL-CRSP): University of California, Davis.
- Coppock DL, Mamo M. 1985. Summary of Borana encampment survey conducted 16 November to 15 December 1985. Internal Memorandum ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.
- Delespaux et al. 2008. In: Solomon TB. 2011. Building climate change resilience for Africa livestock production systems. Unpublished Report. University of Namibia.
- Desta S. 1999. Diversification of livestock assets for risk management in the Borana pastoral system of southern Ethiopia. Doctoral dissertation. Department of Rangeland Resources, Utah State University.
- Desta S, Coppock DL. 2002. Cattle population dynamics in the southern Ethiopian rangelands, 1980-97. *Journal of Range Management* 55:439-451.
- Desta S, Coppock DL. 2004. Pastoralism under pressure: Tracking system change in southern Ethiopia. *Human Ecology* 32: 465-486.
- Desta S, Getachew G, Tezera S, Coppock DL. 2006. Linking pastoralists and exporters in a livestock marketing chain: Recent experiences from Ethiopia. In: McPeak J, Little P, eds. *Pastoral livestock marketing in Eastern Africa: Research and policy challenges*. Warwickshire, UK: Intermediate Technology Publications. p. 109–128.
- Desta S, Tezera S, Gebru G, Kristjanson P. 2011. Summary of baseline household survey results: Borana, Ethiopia. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.
- Elias E. 2009. Threats of climate change on pastoral production under restricted herd mobility: A case study in Borena. Work done for SOS Sahel Ethiopia.
- Gebremichael Y, Kifle M. 2009. Local innovation in climate change adaptation by Ethiopian pastoralists. Report Submitted to PROLINNOVA–Ethiopia and Pastoralist Forum Ethiopia (PFE). Addis Ababa, Ethiopia.
- Huqqa G. 1999. The 37th Gumi Gayo assembly. Gada: the Oromo: traditional, economic and socio-political system. Norwegian Church Aid: Addis Ababa.

- IPCC. 2007. Africa. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
- Isobel B, Grahn R. 2007. Pastoralism – managing multiple stressors and the threat of climate variability and change. Human Development Report 2007/2008. Fighting climate change: Human solidarity in a divided world
- Legesse A. 1973. *Gada: Three approaches to the study of African Society*. New York: The Free Press.
- Nicholson N, Desta S. 2010. Final evaluation: Enhanced livelihoods in the Mendera triangle (ELMT) and enhanced livelihoods in southern Ethiopia (ELSE) program 2007-2009.
- Njoya A. 2009. *Building climate change resilience for African livestock, west and central region*. Yaoundé, Cameroon: Institute of Agricultural Research for Development.
- Oxfam. 2007. *Adapting to climate change: What's needed in poor countries, and who should pay*. Briefing Paper 104.
- [PFE] Pastoral Forum Ethiopia. 2011. Proceedings of the 5th annual pastoral national conference: Climate change and pastoralism: The implications on sustainable pastoral development in Ethiopia. Unpublished report.
- Riche B, Hachileka E, Awuor CB, Hammill A. 2009. Climate-related vulnerability and adaptive-capacity in Ethiopia' Borana and Somali Communities. Final assessment report. Save the Children UK and CARE.
- Troeger, S. 2011. "Everything that is happening now is beyond our capacity" Nyangatom livelihoods under threat. In PFE proceeding. Unpublished report.

9. Forestry and agroforestry land use for climate change adaptation and mitigation

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Abstract

Ethiopia has a long history of agriculture and deforestation. Tree planting on mountain slopes and in watersheds for soil and water conservation, wildlife protection and supporting social welfare practices have been known at least since the early 1400s. Ethiopia has also faced a long history of climate change and variability. Despite the long history of tree planting, deforestation is far exceeding afforestation, reforestation and forest conservation.

Consumption of wood is much higher than the supply, and the country is importing fuel wood to meet its demand. As the country's forest resources are becoming more depleted, the people are also becoming more vulnerable to climate change. Forests can play a vital role in increasing societal adaptive capacity to climate variability if sustainably managed. In Ethiopia, there are management plans to maximize forest profitability for better climate adaptation and mitigation. Regular forest inventory data are entry points for planning any type of forest management activities, which most Ethiopian forests are lacking. Findings from this review show that mixed plantations are more profitable than monoculture stands. For a long time, we believed that slow-growing indigenous tree species are inferior to fast growth exotic species in terms of biomass production. Fast growing exotic tree species have been blamed for their adverse effects on the environment. But under mixed stand management—mixing indigenous tree species like *Junipers procera* with exotic fast growing species like *Eucalyptus spp* and *Cupressuss lusitanica*—it is possible to generate higher annual income and more profits with less environmental impacts than pure stands of *Eucalyptus* and *Cupressus lusitanica*. This is an innovative forest management practice with great potential to increase the profitability of the Ethiopian plantation forests.

Keywords

Sustainable forest management; agroforestry; climate variability; climate change mitigation.

9.1 Introduction

Forests play a vital role in regulating environmental shocks and improving livelihoods and make an enormous contribution to the overall development of a nation. Many developed nations across the globe have rich forest resources and technologies to take advantage of this resource. Most importantly, forests are assets and strategic for coping with natural and anthropogenic environmental hazards. This has already been well recognized by the Ethiopian society; orders from kings on tree planting, conservation and protection had been launched since the 1400s (von Breitenbach 1962). It is, however, worth mentioning that the country's forest development strategies have remained focused on tree planting rather than advancing sustainable conservation, management and utilization.

Ethiopia has experienced several climatic and environmental shocks during the past several thousands of years. The most recent climatic hazards are associated with the recent global warming-induced changes in the earth's climate system. Thus, Ethiopia's rainfed agriculture is facing serious problems as a result of erratic rainfall patterns. The impact of greenhouse gas (GHG) emissions on Ethiopian climate is becoming more evident in recent years, as manifested by an increased number of people affected by droughts and floods. The vulnerability of Ethiopian farmers is also aggravated by poor land management practices, leading to heavy environmental degradation. And yet many farmers are cultivating marginal areas and obtain marginal yields. Adaptation to and mitigation of climate change are the major challenges facing Ethiopian farmers. Thus, developing sustainable forest management is one option that could assist these communities. Maximizing forest profitability through sustainable management would not only benefit the poor but also greatly contribute to supporting the government's national development programmes through promoting exports, taking advantage of climate change opportunities and meeting local needs. In this regard, the existing forest management system is unable to foster forest development for livelihoods and national economic development.

This paper reviews published research papers on forests and climate change in Ethiopia. First, the paper highlights the historical patterns of deforestation and major drivers, followed by development of plantation forests in Ethiopia. Impacts of climate change on forest growth in Ethiopia are also highlighted and discussed as key indicators of climate variability risks. The magnitude of future warming in changing the present forest boundary is demonstrated by the

effect of future temperature rises on increasing evapotranspiration and aridity. Published scientific evidence confirms that a change in the altitudinal belts of forest vegetation is inevitable in Ethiopia as a result of climate change.

Finally, the paper discusses the most important challenges and constraints to management of forests in Ethiopia, presenting a possible sustainable forest management model that enables maximization of profitability of the forest resources. This is based on available yield tables developed for highland plantation forests from growth modelling studies conducted at several replicated sites in the country (Pukkala and Pohjonen 1989, 1993, Pohjonen and Pukkala 1992). Such management models are already used in many countries and have been adopted by forest companies. At federal, regional and project levels, there is limited knowledge and financial constraints to develop and practice such prescribed management models including regular inventory for sustainable management. The impressive part of the model is that it shows mixed stand management is ecologically and economically more profitable than the pure stand management system. This opens avenues for promoting the profitability of indigenous trees species in afforestation and reforestation programmes.

In conclusion, there is need to address the frequently raised issue of institutional setup. Because of the absence of a mandated institution, the profitability of forest resources is not fully exploited and the country's imports of forest and wood products are increasing. For an agrarian country like Ethiopia with good climatic and soil conditions that permit high forest production, importing wood products can be avoided. Therefore the current forest management system in Ethiopia should be changed into a system that permits profitability of forests.

9.2 State of climate change and forests in Ethiopia

9.2.1 Trends, causes and consequences of climate change

State of climate change and variability

The scientific understanding of the potential impact of GHGs and the climate systems has advanced enormously. The potential for changes in atmospheric composition in particular with respect to increased concentration of GHGs (CO₂, N₂O, CH₄, CFCs) that strongly absorb infrared radiation and allow solar short-wave radiation to enter the earth's surface has been known for more than 100 years. Levels of these GHG in the atmosphere are rising causing the

warming of the earth. The predominant GHG is CO₂ and contributes about 50% to overall warming, although its warming effect is weaker than the other gases. Atmospheric CO₂ concentration has increased from 270 ppm in the pre-industrial era to 370 ppm currently (IPCC 2007) due to extensive use of fossil fuels in industrialized nations. According to the IPCC (2007) predictions, global mean temperatures and sea levels follow the same trend: mean global temperatures are likely to rise by 1.4°C by the year 2030 and by 2.1°C by 2050 and global mean sea level will be 20 cm higher by 2030 and 31 cm by 2050.

Increasing global mean temperature and sea level due to increases in GHGs in the atmosphere leads to a shift in the earth's climate system and creates significant threats to natural ecosystems and to human existence. The consequences are enormously negative particularly in tropical Africa where historical vulnerability to climate anomalies is manifested by large human suffering resulting from droughts, floods and subsequent famine.

Trends of climate change and variability

Climate change and climate variability can be documented from analyses of fossilized and fresh biological materials, instrumental records and legendary accounts or historical documents. Widely used proxies for reconstructing past climate and land use history include dendrochronology (tree rings), ice cores, lake sediments, paleosol sediments, and stalagmites. With the exception of the ice cores, all of the proxies have been used to reconstruct historical patterns of climate change and variability, vegetation shifts and human environmental interactions in Ethiopia (Wils et al. 2009, 2010, Gebru et al. 2009). Of these proxies, tree rings and stalagmites combined with stable isotope chronology are high resolution proxies for reconstructing past climate variability, understanding the earth's climate system and hence anticipating future changes.

Series of dendrochronological research have been conducted at regionally replicated sites in the Ethiopian Rift Valley and highlands. As a result, the growth periodicity of trees has been determined (Wils et al. 2009). More than century-scale rainfall variability, drought frequencies and river discharge have been reconstructed by analysing radial growth of tree rings of *Juniperus procera* obtained from northern and southern Ethiopia (Wils et al. 2010).

Similarly, the dendrochronology of *Juniperus procera* obtained from Dodola forest in Bale show a highly significantly correlation with annual total precipitation (Couralet 2007). Dodola forest is located more than 700 km south of the Hugumburda forest. There are also differences

between the two sites in the months when the wet seasons start and end. Despite these differences, however, similarities between the two tree ring chronologies in the patterns of tree ring width matching and their similar correlation to spring precipitation provide evidence that the climate anomalies in general and rainfall variability in particular in Ethiopia might have been due to regional factors rather than local effects.

The chronology of tree ring width growth indices indicates about 22 drought years in northern Ethiopia during the last 132 years, suggesting an average cycle of drought every six years. The drought cycle is becoming more frequent in recent years. Data from the tree ring proxy is in close agreement with what we know from historical records of 321 drought and famine years during the period BC 253 to AD 2001, with a frequency of every seven years. Years of extremely narrow tree ring formation appear to match with years of drought events recorded historically as years of Ethiopian famine. For example, years 1876–1878, 1885, 1888, 1891, 1903, 1932–1934, 1957–58, 1962–63, 1974–1977, 1982–1983, and 2000–2001 were years with the lowest rainfall and caused the highest human and livestock deaths that have been recorded in Ethiopian history. Some of these drought years identified from tree ring growth were consistent with El Niño–Southern Oscillation (ENSO) variability (Ortlieb 2000). For example, the 1877/78 drought corresponded with the Indian drought of 1877, which was related to ENSO and the Indian monsoon climate. A clear matching of the chronology of drought/famine in Ethiopia with the chronology of El Niño has been reported (Degefu 1987). The 1982 drought, for example, was consistent with an El Niño episode. A link between years of El Niño and years of narrow tree ring formation in Ethiopia is well recognized (Gebrekirstos et al. 2008).

The tree ring data is supported by trend analyses of climate data. Climate data for 55 years (1951–2005) show that rainfall in Ethiopia remained more or less constant when averaged over the whole country (Tadege 2008). However, a declining trend is reported for the northern half and southwestern parts of the country, while a slightly increasing trend is reported for the central parts of the country (NMSA 2001, Tesfaye 2009). The annual minimum and maximum temperatures reveal a warming trend with an average increase of 0.1 and 0.25°C per decade (NMSA 2001). In contrast, NAPA reports a warming trend of annual minimum temperature by about 0.37°C per decade.

GHG-induced global warming, severity and frequency of droughts in Ethiopia

As discussed above, evidence shows a clear matching of the chronology of drought and subsequent famine in Ethiopia with the chronology of El Niño (Degefu 1987). Also a link between El Niño and tree ring marker years has been reported (Gebrekirstos et al 2008). Likewise a link between El Niño and La Niña phenomena and historical records of Ethiopian rainfall variability has been recognized. All these are indicating that Ethiopian rainfall had been superimposed by effects of El Niño on the climate systems. The disruption caused by El Niño is well known. El Niños are somewhat erratic, occurring every two to seven years, in the same way as the rainfall pattern varies in Ethiopia.

The semi-arid Sahel climate is known to be sensitive to year-on-year variations, and is characterized by a highly variable, short and intense rainy season typically occurring in August and no more than 4 months long, followed by a prolonged dry season. The climate in Ethiopia, particularly in the northern part, is characterized by a similar pattern of annual rainfall seasonality.

Several studies on the ENSO–Sahel teleconnection provide evidence that in recent decades the Sahel has experienced one of the most striking shifts in climate, from an anomalously wet period in the 1950s and 1960s to progressively drier conditions in the 1970s and 1980s. The cause of persistent droughts in the 1970s and 1980s lies in the oceans and is known to be related to a generalized pattern of warming of the global tropical oceans, especially the Indian Ocean (Lu and Delworth 2005), which in combination with enhanced warming of the southern compared to the northern tropical Atlantic Ocean (Hoerling et al. 2006), weakened the African monsoon. Currently little scientific evidence is emerging on understanding the role of anthropogenic forces especially the emission of aerosols and GHG in influencing such patterns of change in global sea surface temperatures and in Sahel rainfall in general and Ethiopia in particular (Biasutti and Giannini 2006, Cook and Vizzy 2006, Williams et al. 2012).

Recently, model-based research findings show a direct link between global warming and the Sahel drought (Rotstayn and Lohmann 2002). Accordingly, GHG pollution clouds from Europe and North America affect the properties of the clouds in the northern hemisphere. The clouds reflected more sunlight back to space and this cooled the oceans of the northern hemisphere. As a result, the tropical rain bands moved southwards tracking away from the

more polluted northern hemisphere towards the southern hemisphere leading to the failure of the monsoon and the disappearance of the rains in the Sahel during the 1970s and 1980s.

Furthermore, the shift in precipitation sources of Ethiopian rainfall has been recently recognized and is thought to be associated with the influence of GHG-induced global warming. Stable oxygen isotope records in tree rings of Ethiopian *Juniperus procera* primarily reflect year-to-year changes in the proportion of Ethiopian precipitation that was originally derived from the rainforests of the Congo Basin (Williams et al. 2012). According to this recent finding, a post-1940s decline in the proportion of moisture transported out of the Congo Basin toward the Greater Horn of Africa took place. They propose that rapid and ongoing warming within the southern tropical Indian Ocean has led to significant increases in evaporation, convection and precipitation over the Indian Ocean, and a subsequent increase in the amount of dry air that is transported westward through the mid-troposphere toward eastern Africa. The increase in dry airflow toward eastern Africa from the tropical Indian Ocean appears to suppress convective activity over much of eastern Africa. Suppressed convection over eastern Africa weakens the pressure-gradient force that has historically driven moisture transports from the Congo Basin toward Ethiopia and much of the Greater Horn of Africa.

As the Congo Basin acts as the primary source of moisture to much of the Ethiopian highlands, this historical shift in precipitation source and atmospheric moisture transport as well as its subsequent anomalously dry seasons could be substantially further strengthened under global warming. Also, stable C isotope records in more than 100 years of *Juniperus procera* tree ring chronology indicated a linear increase in the concentration of ^{13}C depleted CO_2 resulting from fossil fuel, providing additional evidence on the potential impacts of GHGs in determining the Ethiopian climate pattern (Eshetu 2006). Additionally, land degradation is capable of reinforcing changes to the hydrology arising from inherent decadal rainfall variability at local scale. Model-based studies by Savenije (1995) indicate that the Sahelian drought was most aggravated, if not caused, by a decrease in total evaporation over the years 1970–1980 due to loss of vegetation cover caused by forest removal and overgrazing. The presence of forests would have caused an adjustment in the local surface flux of latent energy, sensible heat and evaporation. This would ultimately reduce the magnitude of the convective rainfall, which is supposed to give rainfall in the Ethiopian

highlands. In this respect, mountain afforestation/reforestation could reinforce the formation of mountain clouds.

9.2.2 State of forest management and development

Historical deforestation

The increasing loss of natural forests and woodlands is becoming a concern for the Ethiopian government and people. Despite significant efforts of local, regional and federal administrations to stop further decline of forest resources, the rate of deforestation continues to increase (Table 9.1). The decline of original forest cover from 40% in the early 1900s to 37% in pre-1950s has been often cited; but available scientific evidences such as historical records, paleo-botanics and palaeosols failed to confirm the large forest cover before the turn of the 1900s. By 1962, 1965 and 1973–76 the forest coverage had decreased to 4.4%, 7% and 4.75%, respectively. In 1985 and 1986–89, the forest coverage of the country was 2.7% and 3.93%, respectively. It seems that there are discrepancies in the trend of deforestation among the datasets reported between 1962 and 1989. The discrepancy might have resulted from differences in the methodology used by different authors. For example, forest cover decline from 4.75% in 1973–1976 to 3.93% in 1986–1990 has been estimated using satellite images (Reusing 1998). The other source of discrepancy is that the total surface area of the country considered for the estimation of forest coverage was different for different studies as indicated in Table 9.1. The third source of discrepancy could be that the studies inappropriately used outdated data in their reports.

Table 9.1. Historical deforestation of the Ethiopian highland forests

Year	Forest cover (ha)	Forest cover (%)	Sources
Beginning of 1900s	53,000, 000	40	Pohjonen and Pukkala (1990)
Pre-950s (original forest)	41,200,000	37	Von Breitenbach and Koukol (1962)
1950s	21,000,000	16	Pohjonen and Pukkala (1990)
1962	5,000,000	4.4	Von Breitenbach and Koukol 1962
1965	9,000,000	7	Pohjonen and Pukkala (1990)
1973-1976	5,441,000	4.75	Reusing (1998)
1986-1990	4,505,500	3.93	Reusing (1998)
1985	3,500,000	2.7	Pohjonen and Pukkala (1990)
2010 Recent estimate		11	FAO (2010)

The percent of the forest cover is calculated as a percentage of the total land mass of 112,800,000 ha, while von Breitenbach and Koukol (1962) used 144,000,000 ha of land as the total surface area of the country to calculate the relative forest coverage.

The 2.7 % forest cover in 1987 reported by Pohjonen and Pukkala (1990), for example, seems to be taken from von Breitenbach and Koukol (1962), who reported that 80% of the 4.4% (5,000,000 ha) in 1962 are located in inaccessible regions. By assuming a loss of 50% of these forests are by planned settlement, and provided that it will be possible to conserve other forests within their present limits, von Breitenbach and Koukol (1962) projected that the definitive forest area of Ethiopia will amount to 3,000,000 ha or 2.6% of the total land surface. After 32 years, Pohjonen and Pukkala (1990) report the same forest cover of 2.7%.

Irrespective of the cause of the discrepancy, the historical deforestation trends suggest that the country had lost about 92.7% of the early 1950s original forest within 35 years (1950–1985) at the rate of 1,077,142 ha per year. If this magnitude of deforestation continued, then complete disappearance of the Ethiopian high forests would have already happened. Again there is lack of consistency in the magnitude of deforestation trends with other reports stating that the country loses its remnant forests at a rate of 150,000–200,000 ha per annum (Kassahun 2008). The FAO (2010) report indicates a substantial increase in forest coverage from less than 4% in the 1980s to 11% in 2010. The increase in forest cover during recent years is attributed to an increase in tree planting on farmlands for economic gain, as well as area ex-closures on degraded mountainous areas for forest restoration. But tree planting in the natural high forests and woodlands is continuing to decline.

The driving forces for the rapid decline of the natural high forests and woodlands are extensive field cropping, cattle grazing, extensive logging of commercial timber and shifting cultivation. According to von Breitenbach and Koukol (1962), in the past, land use in Ethiopia was exclusively limited to primitive field cropping and extensive cattle grazing expanding to forests, as forests were well appreciated as contributing to soil fertility. Also there was no remarkable demand or market because of highly dispersed rural villages, lack of permanent settlements, big towns and industries; and hence there was no need to conserve the forests. Even today, there is a thought that in rapid economic development, forestry involves considerable difficulties on account of its long production period; and hence forests, particularly virgin forests, are seen as free virgin land and highly productive soils for

expanding cultivation of cash crops and sedentary agriculture. All these points of view are continuing and cannot save forests from further degradation, but rather aggravate destruction of primary virgin forests.

As a consequence, the demand for forest products remains much higher than the supply (Table 9.2). Accordingly, the demand was 2.5 and 4 times higher than the supply in 1984 and 1994, respectively. The only positive balance recorded was for 1986, when the consumption was 39 million m³ lower than the supply.

Table 9.2. Supply and demand of fuel wood in Ethiopia

Source	Annual wood supply (million tons)	Annual demand (million tons)	Deficit or surplus
UNDP/World Bank (1984)	8.1	20.34	Demand is 2.5 annual supply
ENEC/CESEN (1986)	63	24	Positive balance
EFAP (1994)	8.6	35	Demand is 4 times higher
UNDP/World Bank (1996)	n.a.	31.5	Deficit indicated
WBISPP (2005)	50.1	53.6	Deficit
EFAP 1994 projection for 2020	-	-	Deficit

n.a. = data not available

Indeed the country is becoming a net importer of various forest products. The country's import volume of industrial forest products is increasing rapidly in parallel to the population growth, forcing the country to spend large amounts of foreign currency ranging between USD 5.4–35 million per year (Limenih 2010).

More importantly, this historical deforestation has resulted in crises of food insecurity. The country loses a soil depth of 8 mm annually with mean annual soil loss of 1900 million tons (130 tons/ha/yr) (FAO 1986, EHRS cited in Kassahun 2008). Consequently, annual loss in grain production increased from 40,000 t in 1997 to 170,000 t in 2000 (Tedla and Lemma 1998), which was equivalent to an annual income loss of USD 150,000 (Barbier 1998).

Plantation forestry: productivity and current management status

Plantation forestry in Ethiopia was started in the 1400s by the order of King Zera-Yakob (1434–1468). The purpose was to enhance the benefits of forests for public welfare through their balancing effects on the catchment hydrology and climate as well as their control of soil erosion and floods. The state organized major reforestation efforts with the introduction of

fast growing exotic species in 1888 when Emperor Menilik (1888–1992) looked for ways of alleviating the shortage of fire and construction wood in the capital. Main consideration was given to the Australian *Eucalyptus* species, *Cupressus lusitanika*, pine species, *acacia deccurrence*, *Juniperus procera* and other more indigenous and exotic tree species. The driving force for the development of large scale reforestation and afforestation projects of mainly exotic species were: i) slow growth of indigenous tree species and thus unable to meet the ever increasing demand for timber and fuelwood; and ii) knowledge on how to grow exotic species was obtained from other east African countries of Kenya and Tanzania, where remarkably superior growth of many exotic plantation forests notably *Cupressus* and pine plantations had been successful in areas with similar ecological and soil conditions as in the highlands of Ethiopia (Lundgren 1978). Accordingly, in the 1950s and 1960s state-organized industrial plantation forest projects were established (Jarvholm and Tivell 1987). Later, during the 1970s and 1980s *Eucalyptus* spp, *Cupressus lusitanica* and *Juniperus procera* and many other tree species were planted for combating deforestation and meeting increased public needs and individual wood demand, especially in the regions where wood shortage was becoming a serious social and environmental problem.

Compared to the rate of deforestation, the development of plantation forestry has been very gradual. The plantation cover in before 1973 was 42,300 ha, of which 40,000 ha were woodlots owned by private entities, and 2,300 ha was owned by the government (FAO 1979). *Eucalyptus* plantations alone reached 15,000 ha around Addis Ababa (von Breitenbach and Koukol 1962). This gradual development of plantation increased to cover more than 85,000 ha in 1980 (FAO 1988) and to 250,000 ha in 1985 (Davidson 1989, Eldrige et al. 1997, Teklu 2003). In 2005, the total area of plantation forests in the country was around 500,000 ha (WBISPP 2004). These plantation forest stands are managed by communities or regional states. Today large portions of these plantations are over matured and have reached the age of more than 30 years while the average rotation age for optimum economic gain from the plantation forests is at 19 years (Figure 9.1 and Figure 9.2) (Pukkala and Pohjonen 1993, Pohjonen and Pukkala 1990). This is an indication that they are not managed in terms of their growth, site conditions, and productivity. Hence, their importance in the country's wood supply is not large enough to meet the ever-increasing wood demand, to reduce the pressure on the natural forests and to contribute to the national economy. However, small-scale woodlots are taking over the crop fields in several areas in the country, as the demand for

wood is increasing with an increase in population growth, and hence offer better income opportunity than food crops (Ewunetu 2010, Limenih 2010).

Figure 9.1. Growth curves for Eucalyptus globulus seedling stand

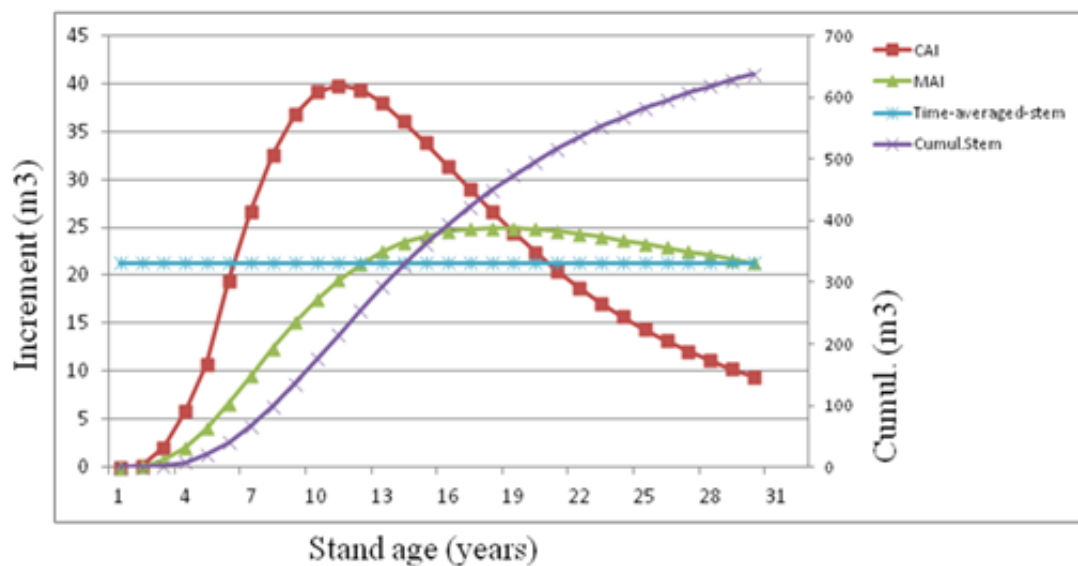
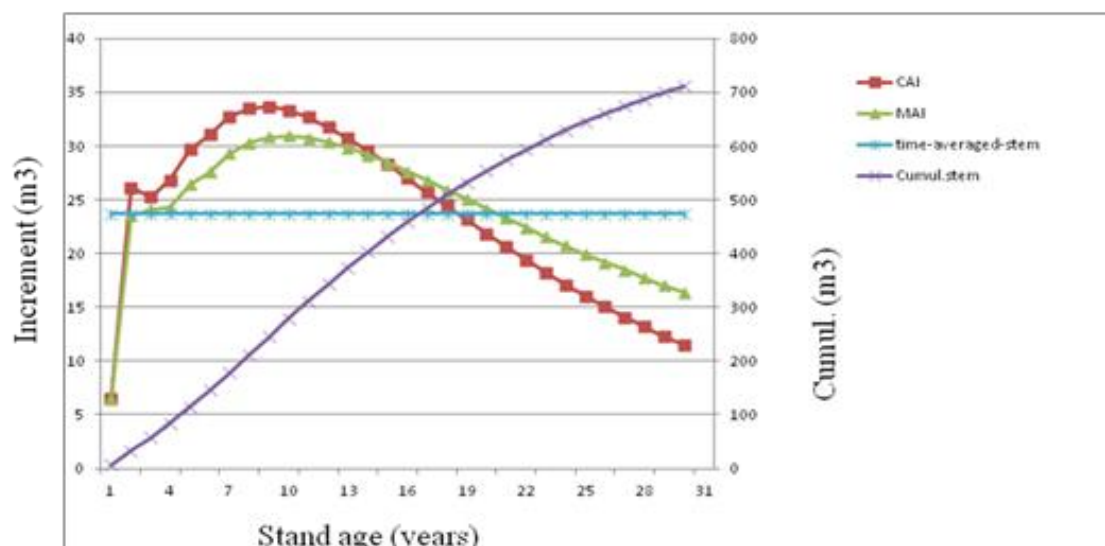


Figure 9.2. Growth curves for Eucalyptus globulus coppice stand



Soils and forest productivity

Although a great majority of exotic species were chosen for their capacity to grow rapidly and produce wood of high yield, the sites chosen for most forest projects in Ethiopia are extremely eroded with extremely poor agricultural potential. Major limitations to using these soils for commercial plantation are low nutrient reserves, poor nutrient retention capacity, and low moisture holding capacity hence trees are susceptible to dieback caused by drought and

disease. Also, continuous removal of foliage and other forest debris from the forest floor for fuel, which otherwise are crucial for maintaining nutrient supply, water retention and structural stability, make it difficult to maintain ecological rehabilitation and enhance productivity of these sites. On the other hand, plantations established close to natural forests for buffering the remnant natural high forests occupy very fertile soils such as nitisols, acrisols and luvisols and have minimum limitations to support commercial forestry.

Forest growth prediction and yield tables are developed for major highland plantation tree species. The yield of the whole rotation of *Cupressus lusitanica* ranged from 225 m³/ha in the poorest site (class IV) to 415 m³ in the best site (class I) with mean annual increment of between 6.6 and 16.6 m³ (Pukkala and Pohjonen 1993). The annual increment of *Eucalyptus globulus* seedling stands varied between 9 m³ for site class IV and 29 m³ for site class I at the rotation age of 19 years after planting. For coppice stands the annual increment is between 13 and 47 m³ for site class IV and I, respectively, with a rotation age of 14 years. The average growth potential of *Juniperus procera* is 7.5 m³/ha/yr at the rotation age of 60 years (Pohjonen and Pukkala 1992).

Generally, for environmental, soil and climatic conditions of mid-elevation sites of the Ethiopian highlands, like those around Addis Ababa, the maximum annual increment of Eucalyptus species (e.g. *E. globulus*, *E. saligna*, *E. gransis* and *E. camaldulensis*) is about 50 m³; while for *Cupressus lusitanica* maximum current annual increment of 20 m³ per ha is obtainable at the age of 10 years (Pukkala and Pohjonen 1989). The productivity of the Ethiopian highland plantation forests are in close agreement with and even much higher for some species, plantations of the same species established on volcanic soils in the Tanzanian and Kenyan highlands (Lundgren 1978).

Current management practices

Data on yield and forest productivity are important entry points for developing sustainable forest management planning for maximizing economic and environmental benefits of forests. As discussed above, yield tables and information on site productivity with subsequent management recommendations are available for major highland plantation forests. Despite this, almost all plantations stands in the country, no matter who owns them—state or community— do not have prescribed silvicultural management planning operations such as pruning, thinning, regular inventory and clear felling schedules. Final and intermediate

harvesting schedule for most plantations is commonly practiced whenever the community's and/or state's demand arises for various wood products such as fuel, construction, but not on the basis of the growth rate, financial or biological maturity and rotation length of the forests stands.

It is likely that the available forest yield or growth tables and knowledge about appropriate species site matching and stand management may not reach or is rarely used by forest managers. Inadequate allocation of government funds for silvicultural operations and lack of periodic forest inventory may also contribute to mismanagement of the plantation forests. As a result, majority of plantation forests in the country are congested or overstocked and over matured, while in some cases they are under-stocked because of illegal felling by local communities. Also foliage, branches, and tops are removed for fuel not only during final harvesting and thinning but also removed continuously from forest litter. They are not being piled in the forest stand. All these lead to increased soil erosion, and soils under tree canopies cannot keep suitable soil moisture balance and nutrient reserves. By having such mismanagement operations in place, fast-growing short rotation plantation forests would adversely affect the environment in several ways. They may reduce productivity and sustainable growth of plantation forests and are major limitations or constraints to development of exotic or indigenous plantation forests for achieving sound environmental and economic benefits. Thus, the environmental capabilities of high yielding short rotation plantations of the Ethiopian highlands are not fully exploited, and the country cannot meet the demands for wood for the domestic and export markets.

Do fast growing plantations adversely affect the environment?

Plantation forests of fast-growing exotic species in general and *Eucalyptus* spp. in particular have been blamed for ecologically harmful effects to the environment. This is because they cause soil degradation and do not allow native vegetation to grow under their canopy due to high nutrient and water consumption associated with their fast growth. However, several studies (e.g. Strobi et al. 2011a, b; Feyera et al. 2002) and field observations provide evidence for their positive effects in fostering rehabilitation of degraded forests and their ecosystem. A recent study by Strobi et al. (2011a) in the Munesa-Shashemen forest shows that the radial growth of *P. falcatus* saplings is three times higher under the canopy of Pinus plantation than under natural forests and Eucalyptus plantation. According to Strobi et al. (2011b), better

growth under the canopy of Pine was attributed to a higher daily uptake of CO₂ due to a higher total light intensity and a higher share of most effective sunflecks. It was also observed that under Eucalyptus plantation the radial growth is comparable to or slightly higher as in the natural forests due to a bigger initial size of the crown (Strobi et al. 2011b). Other studies on regeneration of *Juniperus procera* under the canopy of Eucalyptus at Entoto shows that 1,750 stems/ha of *Juniperus procera* with a full range of age or size gradient, 44% seedling, 13% sapling and 43% pole size under the canopy of *Eucalyptus globulus* with a total stocking density of 2,000 stumps/ha and 7,100 stems/ha of coppice stands. Based on studies of woody species diversity and soil characteristics in an enclosure and in plantations of *Eucalyptus globulus* and *Cupressus lusitanica* in Northern Ethiopia, Abiyu et al. (2011) concluded that degraded land reclamation can be achieved with plantation of rapidly growing tree species as well as enclosure.

Such numerous encouraging results from Ethiopia and other tropical regions suggest that these economically valuable fast-growing, short rotation tree species, with rapid crown closure at an early stage of stand development, may serve as a nurse crop for the slow growing indigenous tree species (Feyera et al. 2002). By doing this, plantation forests buffer natural indigenous plants/tree species and protect them from extinction caused by several adverse conditions. From available data, we should recognize that plantation forests do not adversely affect the forest environment. Rather, poor management practices—such as lack of periodic inventory, regulating stand density, appropriate thinning and pruning, slash management, and unscheduled harvesting—accelerate soil and water degradation. Plantation forests are economically viable and contribute to prosperity of the local community and of the nation if managed.

Natural high and dryland forests

Natural high and dryland forests consist of both young and old growth over-storey and under-storey tree stocking of several species of primary and secondary forests. Their management system is defined as controlled and regular harvesting aimed at sustaining or increasing the commercial, environmental, ecological, biodiversity, aesthetic and cultural values of subsequent stands (Schmidt 1987). The management system of natural forest is more complex than plantation forests, and is based on a logging system. Two silvicultural management

systems, polycyclic and monocyclic, are recognized for managing tropical rainforests (Neil 1981, Jonkers 1987, Lamprecht 1990).

The polycyclic system or selective logging, is a diameter limit felling system where utilization of large diameter trees (usually 50–60 cm) is permitted for logging and by retaining the medium and small diameter trees, a sustainable timber production is secured. The system aims at maintaining uneven-aged forests and encourages development or continued regeneration potential following harvesting by leaving seed trees. The main elements of selective silvicultural and management planning in the polycyclic logging system is to determine commercial species range (harvestable volume), felling limit (minimum diameter at breast height of extracted trees), logging damage (damage to residual trees during logging), wood waste (waste of fractions of wood materials during harvesting and mill processing) and regeneration of commercial species (potential of natural regeneration of tree species following logging operation). In contrast, in the monocyclic system, the entire stock of marketable timber is felled in one single operation with the objective is to creating an even-aged natural forest, which is logged and regenerated under predetermined rotation periods. The silvicultural management in the monocyclic system focuses on the tending of desirable new growth.

Management of natural forests in Ethiopia

Logging of commercial timber from natural forests dates back to the 1900s with the establishment of the first saw mill in Menagesha forest (von Breitenbach and Koukol 1962). Over the course of 50 years, a large portion of the forested area was clear-cut selectively by retaining numerous *Juniperus procera* seed trees scattered on the clear cut areas for the purpose of obtaining natural regeneration. This system of logging and method of regeneration is polycyclic and successfully resulted in what is now seen today as existing pure stands of *Juniperus poles*.

In contrast, expanded logging of high value timber trees of primary forests that had been operated since 1946 by logging companies in the southwest forests is not supported by sustainable management of the natural forests as recommended by Chaffey (1979). Logging concession is focusing on issuing of logging licenses and legal permission and collection of subsequent royalties. The logging operations in several places were neither polycyclic nor monocyclic, and logged-over sites remained under permanent cultivation and grazing.

The first study on the effect of commercial logging on residual stand and regeneration was conducted by Tarekegn (2002). The study assessed the structure and composition, log recovery rate and regeneration status of the logged-over stands in the Godere State Forest in south-western Ethiopia. Accordingly, in the unlogged primary forest, a total of 154 individual trees of 20 species with more than 20 cm diameter at breast height (DBH), out of which 30 trees per ha with average harvested volume of 46 m³/ha are high value commercial trees with more than 20 cm DBH. The estimated proportion of merchantable volume was 28%. The logging intensity was 2 trees/ha that led to damage of 8 trees above 5 cm DBH per tree felled during tree felling. About 10% of the logged-over area was covered by skidding roads, trails, landings, and gaps; and these substantially affected the soil structure and regeneration. With regard to regeneration after logging, Tarekegn (2002) reported species composition and regeneration of major commercial trees under a stand of 2 and 8 years after logging. The larger number of saplings at skidding roads and log landing sites was associated with greater soil disturbance and presence of light seeded, shade intolerant species such as *Croton machrostachyus* and *Cordia africana*. The total estimated number of poles was 263/ha with a total of 22 species; and the number of sapling species decreases with increases in the height of the saplings, suggesting a decrease in species abundance with increases in the age of the regeneration stand after logging. From successfully regenerated species, the only commercial species with adequate regeneration is *Cordia africana*. Regeneration difficulties appeared to be most for primary canopy species such as *Aningeria adolfi-friderici*.

Regarding the logging efficiency, inefficient logging is practiced in the area and this produces a relatively high logging waste of 62% with a log recovery rate 38% for *A. adolfi-friedrici*, which dominates 90% of the logging species. A logging residue as high as 52% comes from the buttress wood part of the tree and the volume of the timber remaining in the forest in the form of buttress wood amounts to 8 m³/tree felled (16 m³/ha), while logging waste due to axe backing is between 2.6% and 3.4%. With this estimated logging recovery rate (6 m³, 36% of the stem volume) and logging intensity (2 trees/ha, 15.63 m³/tree stem volume), a total of 334 trees or a logging area of 166.6 ha is needed for a production of 2000 m³ round wood annually, from which the saw mill produces 720 m³ of sawn wood. This elevated logging waste indicates that unplanned and uncontrolled logging is being practiced. Furthermore, lack of regulation and account for unused logging residue in the annual allowable cut estimates contribute to high logging waste. Also, lack of knowledge on the utilization of buttresses and

large limbs takes the largest share of the waste and leads to considerably high amounts of wood waste during the logging process.

Agroforestry

Agroforestry is a multifunctional, ecologically dynamic natural resource based management system that diversifies and sustains land productivity for increased social, economic and environmental benefits through integration of trees on farms and in the agricultural landscape (Roshetko et al.2007). Agroforestry can be in the form of agricultural crops in combination with forest plantation, tree over crop cover, trees and shrubs in pastures, and woody hedges (for fodder and browse, mulch, green manure, and soil conservation). The multi-storey home garden system is a common practice characterized by perennial or multilayer crops such as coffee, chat, yams, enset, and other food and cash crops existing in south and south-west Ethiopia. Farmers retain upper storey perennial tree crops and provide diet supplement, non-alcoholic stimulant and market income. The home garden system evolved from forests as horticultural traditions. The system is rich in vegetation diversity and stocking with average counting of 21 tree species. Indigenous species account for 85% of the vegetation. The parkland agroforestry system is known by dispersed trees grown in farmlands and is found almost throughout the country. Households mix selected tree species such as *Cordia africana*, *Acacia albida*, *Acacia* species, *Ziziphus* species, and *Balanites aegyptiaca* with crops.

Agroforestry reduces soil degradation and promotes climate resilience, food security, and adaptation to climate change (Garrity 2009). The combination of trees with crops and forages is beneficial to sustainable use of soil water resources and carbon sequestration in site-specific situations especially where farmers are cultivating marginal soils with marginal inputs, produce marginal yields, and perpetuate marginal living and poverty (Lal 2004). Although fertilizer application increases crop yield, its application trend is unchanged since the 1980s indicating purchasing fertilizer is becoming unaffordable for farmers in Ethiopia. The Ethiopian agricultural system is strongly tied to traditional farming technologies. Even during the 20th century, little or no transformation occurred and has remained stagnant for hundreds of years. These challenges of subsistence farming could be addressed by improving soil conditions through agroforestry practices. In agroforestry, where farmers incorporate various tree species on farms, the carbon stock tends to be higher (60–80 ton/ha) just next to natural forests and logged forests (Palm et al. 2004).

Studies of maize yield under conservation agriculture with trees (CAWT) indicates that maize yield under *Faidherbia* is almost four times higher than without (Garrity 2009). The important and commonly recommended management practices in CAWT are zero tillage, cover crop residues, manuring and agroforestry. Adoption of zero tillage in Ethiopian farming systems may face challenges, because crop residues are used as livestock fodder and seed drills are operated manually or by oxen plough. These may cause difficulties in cutting through the residues for placing seeds at the right time and at the right soil depth. Thus, adoption of zero tillage by smallholder farmers in Ethiopia needs serious research with regard to farming techniques and alternative fodder supply.

Church and sacred forests

After long periods of clearing natural high forests and woodlands for fuel, pasture and arable land expansion, several patches of fragmented or isolated trees are conserved and protected as sacred groves in several church and mosque yards, monasteries and burial grounds. These forest resources have been protected for millennia as properties of churches and monasteries for religious and cultural benefits. Studies conducted so far discovered large forest resource bases, species richness, and population structure as well as their religious, biodiversity and medicinal values. There are about 35,000 churches in rural and urban areas throughout Ethiopia, whose compounds are characterized by the presence of old growth forests predominated by *Juniperus procera*, *Olea europaea* subsp. *Cuspidata* and *Celtis africana*.

These forests provide diverse forest products and serve as seed trees as sources of genetic materials for restoration of degraded natural forests. These old growth trees have proven to be useful proxies for reconstructing long term climate variability and advance our understanding on the causes and effects of climate change for establishing mitigation and adaptation strategies through better prediction of climate anomalies (Wils et al. 2010). Additionally, these forests play a vital role in reducing carbon emissions. A recent study conducted in the Addis Ababa Orthodox Churches reported carbon stock density with mean values varying between 129.8 ton/ha for above-ground biomass; 25.9 ton/ha for below-ground biomass; 17.8 ton/ha for litter layer and dead wood and 135.9 ton/ha for mineral soil to a depth of 30 cm (Tolla 2010). These results provide insights into the contribution of forests to carbon emission reduction and enhancing in situ conservation of biodiversity. However, the religious and cultural values are not linked with forest production and management aspects for economic

gains. On the contrary, these forest units are shrinking from time to time and becoming islands of fragmented forests within farms or pasture lands (Figure 9.2). Research and development activities have been initiated on current use and management of these forests for enhancing their role in livelihood improvement, biodiversity conservation and local environmental benefits. So far, there have been no efforts to document the existing local technical knowledge regarding the forests and their proper use by the communities. Thus, the extent of these forests, their use, options for improving their management and expanding their coverage, and opportunities to improve forest quality remain largely unknown.

Figure 9.3. Church forest in northern Ethiopia as a pocket of biodiversity encircled by peasant farms



Source: Google Earth

To address these challenges, the church forests need to be managed sustainably so they can provide economic and environmental benefits to forest-dependent communities within and around the forests. Recent studies on management interventions such as seed sowing, seedling planting, soil scarification, and exclosures as well as on carbon sequestration potentials are encouraging (Tolla 2010). Because of insufficient funds, lack of recognition of their values, and inadequate management skills, the multiple functions of church forests seems unlikely to continue.

Area exclosures

Area exclosures in Ethiopia started nearly four decades ago, when ecological rehabilitation programmes through mountain afforestation and hillside closures were launched on Mt. Yegof, and south Wello in 1973 (Tekle 1988, Eshetu 2002). The approach aimed at

rehabilitating historically eroded mountain slopes and their watersheds and restoring endemic features, through protection of the area from human use and livestock grazing. This approach was combined with improved techniques of land management and gully reclamation. Several government organizations and NGOs led projects of rehabilitation and restoration of degraded lands practicing this technique in a wide range of forest ecosystems throughout the country. Tigray region has had a long history of forest vegetation degradation (Gebru et al. 2009).

Regarding improvement of soil conditions, based on stable carbon isotope studies, Eshetu (2002) reported that after 25 years of area enclosure combined with enrichment planting, the contribution of woody plant to the build-up of soil organic carbon in the 0-5 cm mineral soil amounted to 54%. The total soil organic carbon content in the surface mineral with a concentration of 4–9% was higher than soils in agricultural and pastures land. At the same site, Eshetu (2004) observed a trend of ¹⁵N depleted soil organic matter build up from litter-fall after 25 years of enclosure, confirming that enclosures improve soil chemical and physical conditions through increased litter production, soil organic matter and hence reduced soil erosion.

Protected areas

According to the World Conservation Union (IUCN), protected areas are defined as areas of land and/or sea dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means. With this definition, demarcation and management of protected areas in Ethiopia started mid-1960s by designating ecologically diverse ecosystems for nature conservation across a wide range of ecosystems. This included arid and semi-arid areas, tropical grasslands, savannah woodlands, forests, lakes and wetlands. Currently, there are 50 wildlife protected areas in the country with total area of 75,915 km² (NMA 2007). Management of the protected areas is based on the type of protected area such as national park, wildlife sanctuary, wildlife reserve, wetlands, controlled hunting areas and National Forest Priority Areas (NAFPA). Woodlands, lowland forests and Afro-alpine ecosystems have been designated as national parks and wildlife sanctuaries. The environmental values and role of protected areas in reducing vulnerability risks of climate change and variability is enormous as they provide multiple ecological services. Some of the multiple services include provision of supplemental food production (fruits, grains, wild game, fish); forest products (timber, fuel); water for drinking

and irrigation; enhancing ground water recharge/discharge and water storage; protection of erosion and climate risks; aesthetic and cultural heritage values for recreational and eco-tourism activities; and nutrient cycling at ecosystem level. This multi-functionality, however, seems unlikely sustainable, because the forests are under heavy human pressure from settlement, encroachment of small and large scale farming and grazing, and excessive wood extraction.

Because protected areas cover a wide range of ecosystems, their carbon sequestration potential is high relative to disturbed ecosystems. As part of the Nationally Appropriate Mitigation Action (NAMA), EPA is proposing to manage 7,591,551 ha of protected areas that already have sequestered about 285 million tons of carbon with a C density value of 37 ton/ha. This is higher than that of cultivated land (2.47 ton/ha) and irrigated lands (1.6 ton/ha) (WBISP 2005). The carbon sequestration potential that the protected areas currently have is worth about USD 3.4 billion which is high enough to attract carbon funding for initiating sustainable management and protection programmes.

9.2.3 Socio-economic and environmental values of Ethiopian forests

Direct Economic values

According to Lemenih and Woldemariam (2010) and other sources (cited in Table 9.3), the value of non-wood forestry products (gum, resin, bamboo, wild coffee, ecotourism, honey, civet musk, and medicinal herbs) as well as that of industrial wood products and fuelwood including imported wood products amounted to an annual value of USD 2 billion. From the historical import-export data, the country has had no export volume that exceeded the imports. For example, in the early 1960s, for example, the export values of lumber, charcoal and frankincense were much less than the import value of processed wood products. The country spent 3.5 million Ethiopian Birr on imports against its export value of 0.5 million Ethiopian Birr. Currently, the demand is much higher than the production (Table 9.3), and the country has no exports of wood products.

Given the favourable climatic, soil conditions and other factors to support fast growth of forests in Ethiopia, it is possible to produce more than enough to meet the domestic demand and also save substantial amounts of foreign earnings.

Table 9.3. Direct economic value of forest and non-timber forest products estimates in 2006

Product type	Annual turnover (000' USD)
Non-wood forest products	466,006
Industrial wood production	1,535,152
Industrial wood imports	15,358
Total	2,016,516

Source: Lemenih and Woldemariam (2010)

Potential values from environmental services

The role of forests in regulating the climate, nutrient cycling, water supply and erosion control would assist in increasing adaptive capacity and coping with climate related shocks. In addition, there are cultural, recreational, and genetic resource values that are obtained from forest services. The economic value of Ethiopia's forests has been estimated based on global values. The highest economic values have been attached to soil nutrient cycling (USD 3.7 billion), soil erosion control and sediment retention (USD 980 million), climate regulation (USD 892 million) and recreation (USD 448 million). Values of other forest services such as water regulation and supply, genetic resources, and cultural values are estimated based on the area of currently existing forests, bringing the total economic value of forest services to USD 6.3 billion.

Potential values from forest carbon sequestration

Carbon sequestration value of Ethiopian forests can be inferred from estimations made for Munesa and Sheka forests. The carbon sequestration values of Munesa forests is USD 7.9 million per year, and that of Sheka forests is USD 8.7 million per year. If this carbon stock density could be used as a baseline for estimating the total value of C sequestration of the country's natural forest, then currently standing natural forest cover of 4% (4 million ha) would have a potential to generate USD 360 million annually.

At the national level, however, the WBISPP's (2004) dataset on forest resource surveys and woody biomass assessments is a relevant source of information for estimating the Ethiopian forest carbon. Accordingly, the largest store of carbon in the country is found in the woodlands (1.263 million tons) and the shrublands (952 million tons). However, despite their great potential in influencing the local or global carbon balance, these ecosystems are largely neglected in global discussions and negotiations on climate adaptation and mitigation,

including carbon trading. The total carbon stock in Ethiopian forests is estimated to be 2.764 million tons; which is about 84% of global annual carbon emissions of 3.3 million tons. Given the annual deforestation at the national level of 2% per year, then reducing deforestation could save 57 million tons of carbon annually. This would increase the annual potential revenue by USD 0.6 billion, which is almost equivalent to what the country earns annually from coffee exports.

9.3 Implications for climate change impacts and managing risks

9.3.1 Potential impacts of climate change and variability on forests and society: key vulnerability risks

Impacts on forests

As discussed above, scientific evidence shows that it is certainly true that rates of deforestation and degradation are unrelated to the global warming trends. Rather, it is being recognized that global warming-induced changes in hydrology, rainfall patterns, frequency and intensity of storms, fires, pest and diseases may have far reaching consequences through their impacts on the phenology, productivity, and regeneration of trees. In the southern parts of Ethiopia, series of sediment records analysed for fossilized pollen and charcoal showed temporal shifts in types of forest vegetation as a result of natural climate change and human disturbance. For example, peat core sections from Mt Bada dated 10,000 BP contained a high amount of *Chenopodiaceae* and *Suada* plant species on salt pan soils, which are indicators of semi-desert climatic conditions; while at the same site the upper core section dated 3700-1850 BP is characterized by high amounts of *Juniperus*, *Podocarpus* and *Olea*, indicating a shift towards dryer montane forest ecosystem (Hamilton 1982, Bonnefille 1986). After 1850 BP, the core sediment indicated a decline of *Podocarpus* and its replacement by *Celtis*, *Dodonaea*, *Hagenia*, *Myrica*, *Plantago*, *Rumex* and *Chenopodiaceae*; indicating signs of human disturbance. This shift from semi-desert to montane forest ecosystem at the same place probably had caused local extinction to the biodiversity.

Likewise, analysis of charcoal sediment from northern Ethiopia provided evidence of two phases of climate, cooler during early Holocene (before 6500 BP) and drier since mid-Holocene (after 6500 BP) in the uplands of northern Ethiopia (Gebru et al. 2009). The generally drier environmental conditions led to the expansion of acacia savanna woodlands as

indicated by an increase of C4 grass and *Acacia* species dominated charcoals. The cooler environmental condition was characterized by increased C3 forest vegetation dominated by charcoals derived from a mix of tree species before 2000 BP, just during the Iron Age. These vegetation shifts and subsequent changes in local climatic conditions may be associated with development of human society's ability to use iron tools to permit high agricultural production since 2500 BC. Similarly, if the current increasing trend of atmospheric warming and GHGs emissions continues, it would force species to spatially migrate or become extinct. Predictions by Nkomo et al. (2006) warn that up to 75% of Ethiopian species could migrate, if not become extinct due to climate change.

With regard to vulnerability of forests to the current trend of global warming, general circulation models indicate that as the global temperature increases as a result of the GHG effect emissions, global precipitation also increases. However, according to Goldammer and Price (1998), the increase in potential evapotranspiration due to a warmer atmosphere is far greater than the increase in precipitation, resulting in more negative values of P-E (Precipitation–Evapotranspiration) as the climate becomes warmer. They further elaborate that a 4°C global warming results in a 33% increase in the water-holding capacity of the atmosphere; and to the vegetation this alone is equivalent to 33% decrease in precipitation.

According to NMA (2007), climate change projections for Ethiopia indicate that compared to the 1961–1990 normal, there will be a modest increase in total annual precipitation by about 1.4–3.4% in 2030, 3.1–6.4% in 2050 and 5.1–10% in 2080. At the same time, mean annual temperature will increase by about 0.9–1.1°C in 2030; 1.7–2.1°C in 2050 and 2.7–3.4°C in 2080. The warming trend in Ethiopia is similar to the trend of mean global temperature increases, which will increase by 1.4°C in 2030, 2.1°C in 2050 and 3°C in 2080.

The significantly high positive correlation between evapotranspiration and temperature ($R^2 = 0.82$) indicates that an increase in local temperature by 1°C would lead to an increase of local evapotranspiration by 47 times. This suggests reductions of available soil moisture as the climate warms. For example, total annual evapotranspiration and total annual rainfall in Addis Ababa (with an altitude 2408 m above sea level) is currently 1150 mm and 1225 mm, respectively, and this would amount to positive P-E value of 75 mm. Therefore, a 3°C warming by 2080 (NMA 2007) would result in a rise of total annual evapotranspiration to 1775 mm, causing negative P-E value of -500 mm. Negative P-E values represent dry climatic

conditions. Areas with 1775 mm evapotranspiration and -500 mm P-E values are currently corresponding to climate conditions at Melkawerer (732 masl) and Negele-Borena (1444 masl), respectively. These substantial changes towards drier conditions could certainly lead to upward ecological shifts, and thus shrinking the size of habitat suitable for high value highland plant and animal species.

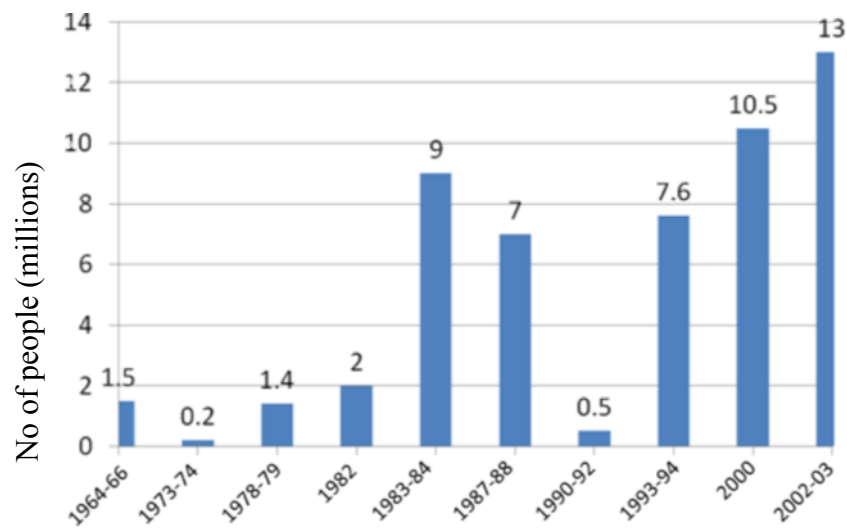
The immediate impact, however, could be manifested by a decline in the health of the forests and their productivity as well as crop yields. Food imports grew from 3% of the total imports in 1975 to 12% in 1990 (CSA 1990). Dendro-chronological studies of tree radial growth located at multiple sites in Ethiopia show nearly 70% of forest growth remains below 130-years average growth as a result of drought-induced soil moisture stress. Based on stable C isotope studies and foliage nutrient analyses, Eshetu (2001) reported tree growth decline of Eucalyptus woodlots around Addis Ababa by observing higher $\delta^{13}C$ values in damaged trees than in healthy trees due to moisture stress. This suggests that economically important tree plantations and woodlots could be vulnerable to seasonal changes in moisture balance as a result of global warming.

The second largest government managed plantation forest *Cupressus lusitanica*—was planted at a rate of 1000 ha/year during 1970s–1980s (Järvholm and Tivell 1987). However, after the Sahelian drought of 1983–1985, the annual planting rate was reduced and partly replaced by a drought resistant indigenous conifer (*Juniperus procera*). Thus there is likely available evidence for the growth decline and sensitivity of both exotic and indigenous tree species associated with global warming. The vulnerability of forests is much lower than that of other sectors such as agriculture. Forests provide a balanced water regime, protection of soils and continuous supply of industrial raw materials as well as assets building that helps communities cope with climate or environmental hazard-related economic crises including substantial decline in yield of food crops.

Impacts on human society

Decline in agricultural productivity as a result of environmental degradation through losses of forests, soils and water resources reduce the resilience of communities to cope with climate change-induced shocks such as droughts, floods and famine. This historical vulnerability to global warming-induced climate variability is given in Figure 9.4.

Figure 9.4. Chronology of El Niño events and number of people affected by droughts in Ethiopia



Source: Degefu 1987

As shown in Figure 9.4, Ethiopia has been historically vulnerable to global warming-induced climate variability. The first highest number of people affected by global warming-induced drought and floods and subsequent famine was during the well-known Sahelian drought of 1983–84. This was followed by the 1987–88 drought that affected about 9 million people and 7 million livestock. Since 1993/94, societal vulnerability to drought and floods increased two-fold by 2002–2003, with 13 million people being affected. Though the magnitude of the effects of the 1964–1965 drought was much less than those after 1980s, it was the most famous in Ethiopian drought history, because it is thought to be the cause for the collapse of the late monarchy.

9.3.2 How should we adapt, mitigate and manage climate change risks?

Maximizing profitability of sustainable plantation forests management

The entry point for sustainable forest management is to determine the productivity or production capacity of a given forest site expressed in terms of site quality or site index. In this regard availability of forest yield tables or growth models is very important. All this information is valuable in developing a prescribed management schedule, which includes silvicultural operations and final harvesting at an appropriate forest age. A potential and actual forest growth-based management schedule improves the quality of the forest product and enhances its economic and ecological benefits.

Prediction yield tables can be used to demonstrate how to maximize profitability of plantation forests in Ethiopia and promote a Climate Resilience Green Economy (CRGE) which would ultimately reduce vulnerability to climate change by improving livelihoods. The focus here is to provide insights into how highland plantation forests should be managed for better environmental and economic gains. The parameters (such as biomass, stem volume, and basal diameter) contained in the yield tables can be used to calculate the carbon stock and value of forest wood in relation to forest stand development. The growth yield of each of the four site classes were averaged to produce a single site class which is an intermediate between the best and the poor sites.

In the Ethiopian highlands, growing *Eucalyptus globulus* plantations, especially enhancing the coppice growth, leads to rapid uptake of C. Such biomass grown in short rotation plantations can be an alternative to fossil fuels in providing energy and thereby decrease C emissions, and increase economic gains from carbon trading. Total annual income from wood products and carbon selling is estimated to be USD 835. Comparing the seedling stands of *Eucalyptus globulus* and *Cupressus lusitanica* in their mean annual carbon uptake, *Eucalyptus* shows rapid uptake of carbon, peaking at the age of 17, and the corresponding time-averaged total annual carbon and wood product amount to USD 496/ha; while that of *Cupressus lusitanica* is USD 425/ha at the age of 20 years. Time averaged carbon uptake for *Eucalyptus* plantation is higher than the carbon uptake at the rotation age. In contrast, *Juniperus procera* plantations exhibit a gradual increasing rate of carbon sequestration up to the age of 200 years, but peaking at maximum carbon sequestration at the age of 40–60 years giving a time averaged total annual income of about USD 330/ha, with cumulative value of USD 13,214 at the age of 40 years. Also *Juniperus procera* stands are preferably used for timber, and timber size is reached at the age well above the rotation age of *Eucalyptus* and *Cupressus lusitanica*. Therefore C sequestration with *Juniperus procera* continues to occur even much later compared to the fast-growing tree species. The estimated time-averaged values indicate that the plantations could have a high potential of generating a total income between USD 330/ha/year and USD 835/ha/year depending on the type of plantation. This would promote asset building for increasing adaptive capacity to climate shocks.

Shifting from monoculture to mixed stand management

Plantation forests in Ethiopia have been blamed for damage to the environment with no substantial scientific evidence showing the impacts both from the environmental point of view as well as the socioeconomic aspects. As discussed in section 9.2.2, it is not the tree species to be blamed, but it is mainly the management system. One of the most blamed species in this regard is *Eucalyptus*, which is used largely in countries like Brazil and South Africa for large scale timber production and as a major export commodity.

Provenance improvement through selection, breeding, genetic engineering, and vegetative propagation should be supported by various types of plantation management for sustained forest production and environmental protection. One such option is the mixed stand management system. Mixed stand management consists of forest-mix by species and age because trees of the same species have different growth and productivity at different sites, while trees of different species have different productivity at the same site and age. A shift from monoculture to mixed stand management is believed to improve the adverse effects of the short rotation plantations on the environment as well as increase the productivity of the forest stands. The mixed stand management system provides better opportunities for maximizing forest profitability and better land management, by mixing high value timber species and N-fixing trees species. The focus here is to demonstrate how an economically viable and ecologically/environmentally sustainable mixed stand management model can be developed for the Ethiopian highland plantation forests based on the available forest yield data (Pohjonen and Pukkala 1990, Pohjonen and Pukkala 1992, Pukkala and Pohjonen 1993).

Operating a mixed stand management system, however, is more complicated and increases input costs compared to monoculture systems. There are plenty of cases in the highlands of Ethiopia indicating that local indigenous species such as *Juniperus*, *Podocarpus* and several acacia species show good regeneration and growth performance on degraded sites under the canopy of *Eucalyptus*.

There are several combinations of mixed stand management system: i) species mix of an even aged stand structure; ii) a mix of age groups of the same species; and iii) species mix with uneven aged structure. Research efforts should also focus on testing and evaluating if the various combinations of mixed stands could provide high economic returns and environmental benefits from a continuous harvest cycle during successive rotations.

In conclusion, for better economic gains in terms of environmental services as well as for promoting the government's commitments towards implementing CRGE, African Green Great Wall, REDD+, CDM, NAMA, and GaTP programmes and achieving their goals, the Ethiopian forests should be developed and managed in a way that forests are generally managed depending on tree growth behaviour and their site specifications.

9.4 Conclusions

There is no doubt that sustainable forest management systems are ecologically acceptable and economically viable. There are several ways of managing plantation and natural forests sustainably as discussed in previous sections of this paper. Having these management systems in place, it is possible to obtain more benefits from the forests. Forest administration in Ethiopia has limited managerial and technical capacity as well as lack of operational guidelines to make any kind of forest management operational. Key challenges include:

- Lack of profit-oriented timber companies;
- Periodic forest growth and site inventory is not considered as the most important part and routine work of the plantation management, and lacks strong teams for this purpose;
- Lack of synergy among education, research and development centres;
- Less attention to the impacts of forests to adapt and mitigate climate change needs sector-mandated institutional arrangement. Most importantly, maximizing the profitability of the sector is constrained by unstable/frequent institutional restructuring.

As a consequence, almost all of community or state-owned plantation forests do not have annual/periodic work schedules, and campaigns of large scale public mobilization for tree planting should be accompanied by sound management practices.

In order to achieve substantial progress towards sustainability of Ethiopian forests and respond to the rising issues on climate change mitigation and adaptation, social and economic values, the following interventions are proposed:

- Evaluate the existing plantation forests for decision making on their utilization and future management;
- Strengthen managerial and technical capacity of forestry staff through providing adequate in-service training and technical guidelines;

- Address issues of establishing fully mandated institutions for forestry development and enhance capacity for managing national forest resource database;
- Create a system that cuts across development, education, research sectors and other key development partners, and minimize the gaps; and
- Create an interface where research outputs can be used to inform policies and decisions.

References

- Abiyu A., Lemenih L, Gratzner G, Aerts R, Teketay D, and Glatzel G. 2011. Exclosure and in plantations of *Eucalyptus globulus* and *Cupressus lusitanica* in Northern Ethiopia. *Mountain Research and Development* 31:144-152.
- Barbier E.1998. The economics of land degradation and rural poverty linkages in Africa. The United Nations University.
- Biasutti M, Giannini A. 2006. Robust Sahel drying in response to late 20th century forcings. *Geophysical Research Letters* 33: L11706.
- Bonnefille R, Buchet G. 1986. Forest history in Ethiopia, a pollen diagram from Wenchi.
- Chaffey DR. 1979. South-west Ethiopia Forest Inventory Project. An Inventory of Forest at Munessa and Shashemene. Project Report 29. London, United Kingdom: Land Resources Division, Ministry of Overseas Development.
- Cook KH, Vizy EK. 2006. Coupled model simulations of the West African monsoon system: 20th century simulations and 21st century predictions. *Journal of Climate* 19: 3681–3703.
- Couralet C, Sass-Klaassen U, Sahle Y, Sterck F, Bekele T, Bongers F. 2007. Dendrochronological investigations on *Juniperus procera* from Ethiopian dry afro-montane forests. *TRACE* Vol. 5: 73-79
- [CSA] Central Statistics Authority. 1990. Ethiopian Statistical Abstract. Addis Ababa, Ethiopia.
- Davidson J. 1989. The Eucalyptus Dilemma: Arguments for and against Eucalyptus planting in Ethiopia. The Forestry Research Center Seminar Note Series No.1. Addis Ababa: Forestry Research Center.
- Degefu W. 1987. Some aspects of meteorological drought in Ethiopia. In: Glantz MH, ed. *Drought and Hunger in Africa: Denying Famine a Future* Cambridge University Press p.23–36.
- Eldridge K, Davidson J, Hardwood C, van Wyk J. 1997. Eucalypt domestication and breeding. Oxford Science publication, Clarendon Press, Oxford. p. 24-26.
- Eshetu Z. 2002. Historical C3 and C4 vegetation pattern on forested mountain slopes: Its implication for ecological rehabilitation of degraded highlands of Ethiopia by afforestation. *Journal of Tropical Ecology* 18: 743-758.
- Eshetu Z. 2004. Natural $\delta^{15}N$ abundance in soils under young-growth forests in Ethiopia. *Forest Ecology and Management* 87:139-147.
- Eshetu Z. 2006. Dendroclimatological Research in Ethiopia. Addis Ababa: Ethiopian Institute of Agricultural Research, Forestry Research Centre. 19pp.

- Ewunetu Z. 2010. Determinants of smallholder farmers' tree growing in the highlands of Ethiopia. In: Eshetu Z, Kassa HM, eds. *Proceedings of the round-table meeting on agroforestry, smallholder woodlot and community forestry for livelihood and environmental resilience in Ethiopia*. 20-21 October 2009, ILRI, Addis Ababa, Ethiopia.
- FAO. 1979. Eucalyptus for planting. FAO Forestry Series No. 11, Rome, Italy. pp. 75-76.
- FAO. 1986. Ethiopian highlands reclamation study. Final report, Volume I. FAO: Rome, Italy. 334 pp.
- FAO. 1988. The Eucalyptus Dilemma. Rome, Italy, pp. 5-23.
- FAO. 2010. Global Forest Resource Assessment. Rome.
- Feyera S, Bech E, Luttge U. 2002. Exotic trees as nurse-trees for the regeneration of natural tropical forests. *Trees-Structure and Function* 16: 245-249.
- Garrity D. 2009. Agroforestry for Ethiopia: Building a new foundation of collaboration. In: Eshetu Z, Kassa HM, eds. *Proceedings of the round-table meeting on: Agroforestry, smallholder woodlot and community forestry for livelihood and environmental resilience in Ethiopia*. 20-21 October 2009, ILRI, Addis Ababa, Ethiopia.
- Gebre Kirstos A, Mitlohner R, Teketay D, Worbes M. 2008. Climate-growth relationships of the dominant tree species from semi-arid savanna woodland in Ethiopia. *Trees* 22: 631-641.
- Gebru T, Eshetu Z, Huang Y, Woldemariam T, Strong N, Umer M, DiBlasi M, Terwilliger VJ. 2009. Holocene palaeovegetation of the Tigray Plateau in northern Ethiopia from charcoal and stable organic carbon isotopic analyses of gully sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology* 282: 67-80.
- Goldammer JG, Price C. 1998. Potential impacts of climate change on fire regimes in the tropics based on MAGICC and a GIS GCM-derived lightning model. In: Markham A, ed. *Potential impacts of climate change on tropical forest ecosystems*, pp. 133-156.
- Hamilton AC. 1982. *Environmental History of East Africa*. Academy press.
- Hoerling MP, Hurrell JW, Eischeid J, Phillips AS. 2006. Detection and attribution of 20th century northern and southern African monsoon change. *Journal of Climate* 19: 3989-4008.
- IPCC. 2007. Africa. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
- Järholm Å, Tivell A. 1987. Industrial forestry development in Ethiopia. Addis Ababa: Ministry of Agriculture. 49 pp.

- Jonkers WBJ. 1987. Vegetation structure, logging damage during planned and unplanned logging operations in eastern Amazon. *Forest Ecology and Management* 89: 59-77.
- Kassahun D. 2008. Impacts of climate change on Ethiopia: A review of the literature. In: Climate Change: A burning issue for Ethiopia. Proceedings of the 2nd Green Forum Conference held in Addis Ababa, 31 October – 2 November 2007. Addis Ababa, March 2008; pp. 9-32.
- Lal R. 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science* 304:1623-1626.
- Lamprecht H. 1990. Silviculture in the tropics. Tropical forest ecosystem and their tree species: possibilities and methods for their long term utilization. Dt. Ges. Fur Techn. Zusammenarbeit (GTZ) GmbH, Eshborn. (Transl. by John Brose Rossdorf: TZ-Verl.-Ges., Germany.
- Lemenih M, Woldemariam T. 2010. Review of forest, woodland and bushland resources in Ethiopia up to 2008. In: Edwards S, ed. *Ethiopian Environment Review No 1, 2010*. Addis Ababa: Forum for Environment. P. 131–186.
- Limenih M. 2010. The role of plantation forests in local livelihood, the environment and climate change In: Eshetu Z, Kassa HM, eds. *Proceedings of the round-table meeting on agroforestry, smallholder woodlot and community forestry for livelihood and environmental resilience in Ethiopia*. 20-21 October 2009, ILRI, Addis Ababa, Ethiopia.
- Lu J, Delworth TL. 2005. Oceanic forcing of late 20th century Sahel drought. *Geophysical Research Letters* 32: L22706.
- Lundgren B. 1978. Soil conditions and nutrient cycling under natural and plantation forests in Tanzanian highlands. Reports in forest ecology and forest soils 31, Department of forest soils, Swedish University of Agricultural Sciences, Uppsala. 429 pp.
- Neil PE. 1981. Problems and opportunities in tropical rainforest management. CFI Occasional paper 16. University of Oxford, Oxford, UK.
- [NMA] National Meteorological Agency. 2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. Report of the Federal Democratic Republic of Ethiopia, Ministry of Water Resources, and National Meteorological Agency. Addis Ababa, Ethiopia.
- NMSA. 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). Addis Ababa, Ethiopia. (Available from <http://unfccc.int/resource/docs/natc/ethnc1.pdf>) (Accessed on 24 June 2013)
- Ortlieb L. 2000. The documentary historical record of El Nino events in Peru: An update of the Quinn record (sixteenth through nineteenth centuries). In: Diaz H, Markgraf V, eds. El

- Nino and the Southern Oscillation: Variability, Global and Regional Impacts. Cambridge: Cambridge University Press, p. 207–295.
- Palm C, Tomich T, Van Noordwijk M, Vosti S, Gockowski J, Algre J, Verchot L. 2004. Mitigating GHG Emission in the humid tropics: Case studies from the Alternatives to slash burn program (ASB). *Environment, Development and Sustainability* 6:145-162.
- Pohjonen V, Pukkala T. 1990. Eucalyptus globulus in Ethiopian forestry. *Forest Ecology and Management* 36: 19-31.
- Pohjonen V, Pukkala T. 1992. Juniperus procera Hochst. Ex. Endl. in Ethiopia. *Forest Ecology and Management* 49: 75-85.
- Pukkala T, Pohjonen V. 1989. Yield models for Ethiopian Highland Eucalyptus. New York: United Nations Sudano-Sahelian Office. 53 pp.
- Pukkala T, Pohjonen V. 1993. Yield of Cupressus lusitanica in Ethiopia. *East African Forestry Journal* 59: 57-73.
- Reusing M. 1998. Monitoring of Natural High Forests in Ethiopia. Government of Ethiopia in cooperation with GTZ, Addis Ababa.
- Roshetko JM, Nugraha E, Tukan JCM, Manurung G, Fay C, van Noordwijk M. 2007. Agroforestry for livelihood enhancement and enterprise development. (Available from <http://www.worldagroforestry.org/downloads/publications/PDFs/pp07395.pdf>) (Accessed on 19 August 2013)
- Rotstayn LD, Lohmann U. 2002. Tropical rainfall trends and the indirect aerosol effect. *Journal of Climate* 15: 2103–2116.
- Savenije HHG. 1995. New definitions for moisture recycling and the relationship with land use changes in the Sahel. *Journal of Hydrology* 167: 57-58.
- Schmidt R. 1987. Tropical rainforest management. *Unasylva* 39: 2-17.
- Strobi S, Fetene M, Beck E. 2011a. Canopy effects on natural regeneration of Podocarpus falcatus in a montane forest of Ethiopia.
- Strobi S, Fetene M, Beck E. 2011b. Analyses of the shelter tree-effect of natural and exotic forest canopies on the growth of young Podocarpus falcatus trees in southern Ethiopia. *Trees* 25: 769-783.
- Tarekegn A. 2002. The influence of selective logging on residual stand and regeneration in a tropical rain forest in southwestern Ethiopia. Dissertation.
- Tedla S, Lemma K. 1998. Environmental management in Ethiopia: Have the national conservation plans worked? Environmental Forum. OSSREA publ. No.1.
- Tekle T. 1988. Ecological rehabilitation of degraded hill slopes in southern Wello, Ethiopia. Doctoral thesis. Uppsala University, Uppsala, Sweden.

- Teklu G. 2003. Expansion of plantation forest in Ethiopia. An outcome of more than half a century's effort. Addis Ababa, Ethiopia: Ministry of Agriculture.
- Tesfaye M. 2009. A synopsis of climate change & its impacts: global and country level. In: Proceedings of National Advocacy Workshop on Wetlands and Climate Change, EWNRA, held in Addis Ababa, 2-3 Dec 2009; pp. 36-68.
- Tolla TT. 2010. Estimation of Carbon stock in church forests: Implications for managing church forests for carbon emission reduction. Msc. Thesis, Environmental Science Program, College of Natural Science, Addis Ababa University.
- Von Breitenbach F, Koukol J. 1962. Menagesha state forest: A description of the forest, its management and its future development including the national park project. Ethiopian forestry review No. ¾: 15-34.
- WBISPP. 2004. Woody Biomass Inventory and Strategic Planning Project; Forest Resources of Ethiopia. Addis Ababa, Ethiopia.
- Williams AP, Funk C, Michaelsen J, Rauscher SA, Robertson I, Wils THG, Koprowski M, Eshetu Z, Loader NJ. 2012. Recent summer precipitation trends in the Greater Horn of Africa and the emerging role of Indian Ocean sea surface temperature. *Climate Dynamics* 39: 2307-2328.
- Wils THG, Robertson I, Eshetu Z, Sass-Klaassen UGW, Koprowski M. (2009) Periodicity of growth rings in *Juniperus procera* from Ethiopia inferred from crossdating and radiocarbon dating. *Dendrochronologia* 27: 45-58.
- Wils THG, Sass-Klaassen UGW, Eshetu Z, Brauning A, Gebrekirstos A, Couralet C, Robertson I, Touchan R, Koprowski M, Conway D, Briffa KR, Beekman H. 2010. Dendrochronology in the dry tropics: the Ethiopian case. *Trees* 25:345–354.

10. Assessment of agrobiodiversity for food security and climate change adaptation

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Abstract

Agrobiodiversity is the result of natural selection processes and the careful selection and innovative developments of local farmers. Agrobiodiversity is a major building block for food security. Conservation and effective management of agrobiodiversity is essential to respond to challenges such as population growth and climate change. However, loss of crop genetic resources and associated traditional knowledge is a critical problem for Ethiopian farmers. The dry sub-humid and semi-arid regions of Ethiopia have erratic rainfall. A crop like teff is adapted to a wide range of environments ranging from semi-arid to waterlogged soils. Other crops include finger millet, sorghum and some unique variants of barley, and wheat.

Keywords

Agrobiodiversity; climate variability; climate change; genetic diversity.

10.1 Introduction

10.1.1 Economy of Ethiopia

Ethiopia is one of the world's poorest countries. Out of a total population of 83 million people, 30 million are living below the poverty line. In addition, 12 million people are chronically or at least periodically food insecure, while only 40 million people are self-sufficient.

Agriculture contributes significantly to the economy of Ethiopia. About 65 million people are engaged in agriculture, predominantly smallholder farmers. Over 12 million hectares is under cultivation, producing most of the staple grains such as wheat, teff, barley, oats, sorghum, maize, millet and pulses such as chickpeas, peas, beans, and lentils. Ethiopia has diverse agro-ecological zones, diverse flora and fauna, as well as diverse culture and indigenous knowledge of local farmers making the country a centre of genetic diversity for many economically important crops such as teff (*Eragrostis tef*), Niger seed (*Guizotia abyssinica*), enset (*Enset ventricosum*), coffee (*coffee arabica*), chat (*catha edulis*), cabbage (*brassica carinata*), wheat (*writicum durum*), and barley (*hordeum vulgare*) (Vavilov 1951).

10.1.2 Agrobiodiversity

Agrobiodiversity encompasses the variety and variability of animals, plants and microorganisms that are necessary for sustaining key functions of the agro-ecosystem, including its structure and processes for, and in support of food production and food security (FAO 1999). It comprises the diversity of genetic resources of species and the diversity of non-harvested species that sustain production (soil microorganisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems.

Agrobiodiversity is the result of the interaction between the environment, genetic resources, management systems and practices used by culturally diverse communities. It is the result of natural selection processes and the careful selection and inventive developments of indigenous farmers, herders and fishing populations over millennia. Agrobiodiversity is a vital sub-set of biodiversity. Many people's food and livelihood security depend on the sustained management of various biological resources that are important for food and agriculture.

Agrobiodiversity plays a fundamental role in ecosystems, securing pest control, pollination, control of erosion and biomass production. Less genetic diversity means fewer opportunities for the growth and innovation needed to boost agriculture at a time when population is increasing and the world is facing critical environmental challenges.

Evidence shows that agrobiodiversity can conserve the ecosystem of essential organisms. It can also increase natural soil fertility and reduce pests and diseases. The effect of a conserved ecosystem can stabilize farming systems. Therefore, a properly conserved agrobiodiversity—plant, animal and microorganisms—will have a significant impact in increasing productivity and food security.

10.1.3 The importance of agrobiodiversity in coping with climate variability

Agrobiodiversity is a major building block for food security and its conservation is essential to responding to the challenges of rapid population growth and climate change. Ethiopian farmers are highly vulnerable to seasonal climatic shocks such as droughts (Dercon and Christiansen 2007). Farmers diversify their livelihoods to manage risks. Preservation of intracrop diversity is one of the diversification options to reduce the likelihood of crop failure (Di Falco et al. 2007). Farmers grow a number of crops either in combination or in succession schemes to reduce the impact of unpredictable and variable rainfall. They also have mixed livestock holdings, including cattle and smaller animals, enabling them to flexibly liquidate some of these assets in times of climatic fluctuations. Further, a large share of the rural population is engaged in non-farm activities (van den Berg and Kumbi 2006). Livelihood diversification is pronounced in the Hararghe region of eastern Ethiopia, which faces a permanent threat of severe droughts. Households in Hararghe have been experiencing repeated lack of food and crop seeds for many years now, hence, a number of non-governmental organizations (NGOs) have been active in Ethiopia providing emergency relief to the affected communities. Due to climatic uncertainty, farmers expect variable agricultural incomes and have devised coping methods such as accumulating assets often in the form of livestock that is sold in times of economic and climatic shocks.

The selection criteria of crop types, species and varieties as well as in managing livestock by the Ethiopian small scale subsistence farmers is part of their wider livelihood diversification strategy. Since Ethiopian climate is variable in time and space, farmers have an advantage of

planting different crop species and varieties. Accordingly, agrobiodiversity can be seen as a natural insurance mechanism (Baumgärtner 2007).

The negative impact of climate change on agriculture is well understood. Ethiopia has one of the largest areas under wheat cultivation among sub-Saharan African countries. Wheat is economically important because of its kilocalorie content. Almost all Ethiopians eat wheat in one form or another. However, with the effects of climate change, its yield could be reduced by more than 75% (Naylor et al. 2007).

Resilience to climate change in agricultural systems requires both agro-ecosystem resilience (the persistence and sustainability of yield from the land in the face of climate change) and livelihood resilience (achieved through livelihood strategy diversification such as planting a wider variety of crop species). Many characteristics found in indigenous breeds will become increasingly important as climate change alters the environment and pattern of spread of pathogens.

Small-scale farming can provide diversified diets including a wide range of cereals, legumes, fruits, vegetables and animal-derived products. In addition to the benefits for consumers' health, this diet also has its implications for climate change mitigation. Majority of climate change mitigation activities are cornerstones of organic agricultural practice, meaning that organic production systems arguably serve as the best widespread examples of low emissions agriculture to date. Organic systems also tend to be more resilient than industrial systems in terms of withstanding environmental shocks and stresses including drought and flooding (Edwards et al. 2000).

10.1.4 Status of Ethiopian agrobiodiversity

The critical problem today is the great loss of significant crop genetic resources and their associated traditional knowledge. The loss of these resources is as a result of many factors such as population growth, market development, the negligence of indigenous knowledge and technological change. A key factor is the adoption of high yielding crop varieties or new crops that replace valuable landraces as well as locally varied food production systems that are under threat. With this decline, agrobiodiversity is disappearing, and the scale of loss is extensive. With the disappearance of harvested species, varieties and breeds, a wide range of unharnessed species also disappears (FAO 1999).

The main cause of the genetic erosion of crops is the replacement of local varieties by improved or exotic varieties and species. Frequently, genetic erosion occurs as old varieties in farmers' fields are replaced by newer ones. Genes and gene complexes, found in many farmers' varieties, are not contained in the exotic species. Often, the number of varieties is reduced when commercial varieties are introduced into traditional farming systems. While FAO (1996) states that some indicators of genetic erosion have been developed, few systematic studies of the genetic erosion of crop genetic diversity have been made. Furthermore, in the FAO Country Reports (FAO 1996) nearly all countries confirm genetic erosion is taking place and that it is a serious problem.

10.1.5 The dilemma in conserving agrobiodiversity

Food security and conservation of important agricultural biodiversity are key challenges for Ethiopia. In order to minimize the adverse effect of climate variability and related risks the absolute solution is conserving and maintaining the valuable landrace varieties. But it is also necessary to use high yielding varieties to alleviate poverty and improve food self-sufficiency. Both approaches have been implemented. The considerable seed and germplasm exchange within and between farming communities is a normal process. It is critically important to pay maximum effort in having a diversity of landraces always on hand, so that any improvement in food security and livelihoods would result in a decreased need to aggressively replant, resulting in real genetic erosion. Certainly improved food security for farmers should be a priority in relief and development agenda for the country. However, it remains to be seen if this can be done while at the same time continuing with in situ conservation of important landrace agrobiodiversity.

10.2 Climate change impacts on agrobiodiversity

One of the impacts of climate change is flooding, which is the main cause for loss of soil biodiversity. The variability and variety of microorganisms are critically important for stability of agrobiodiversity in the soil. There are typically one billion bacterial cells and about 10,000 different bacterial genomes in one gram of soil. Earthworms often form the major part of soil fauna biomass, representing up to 60% in some ecosystems (The Development Fund 2010). The elimination of earthworm populations can reduce the water infiltration rate in soils by up to 93%.

Ethiopian farmers have fragmented land sizes—often less than half a hectare. According to Unruh (2004), high population density and frequent severe agricultural problems provide the food insecurity context in which issues of genetic erosion or conservation operate in Ethiopia. Drought is the main threat to crop diversity. Climate variability, drought, and the subsequent food insecurity affect Ethiopian highland agriculture with a high frequency and severity. While drought has particular influence on food insecurity, flooding, frost, hail and variations in seasonality also significantly affect agriculture. When human vulnerability is high, small variations in climate have relatively greater negative effect.

Agriculture in the highlands of Ethiopia has a number of features. Due to the very long periods of agricultural cultivation, the highlands are heavily populated. The land size per head is usually less than one hectare that cannot produce large quantities. Small land size and large family size coupled with high frequency of harsh agricultural problems results in food insecurity.

In the 2011 crop season, climate variability created a favourable condition for fungal diseases in most parts of Ethiopia. This was more severe on improved varieties of wheat in the central highland and western parts of Ethiopia. However, the local landraces of wheat and teff varieties were highly resistant.

10.3 Sustainability of Ethiopian agrobiodiversity

Ethiopia is one of several countries of the world where crops were domesticated from wild species. Continuous interaction of cultivated crops with their wild relatives under diverse ecological, social and economic conditions have contributed to make Ethiopia one of the most heterogeneous areas of the world in terms of genetic diversity of landraces. Even crops which were originally domesticated outside of the country now exhibit extreme secondary diversification.

Landraces are genetically diverse forms of cultivated plants. They are a subset of biodiversity at the interface between wild plant species and domesticated biota which are manipulated by humans. Through selection, adaptation and exchange of genes with wild species, they represent the repositories of traits which have evolved in local environments over long periods of time. Landraces have provided resources from which modern, and often higher yielding, crop varieties have been developed.

The genetic diversity found in Ethiopian landraces has been used worldwide by international breeders as a resource in building blocks to discover new cultivars. The Ethiopian landraces are importance worldwide, not only for scientific crop improvement, but also to subsistence agriculture of small-scale farmers in Ethiopia. Landraces are managed in low-input agro-ecosystems and can serve as important resources from which to develop new varieties for low-input agriculture and contribute towards more environmentally friendly and sustainable.

Countless useful genetic variations of global significance have originated at the local farm and rural community level. Among the examples are the yellow dwarf virus resistant gene found in Ethiopian barley, on which California's USD 160 million annual barley crops depend as well as the high lysine gene in sorghum, also of Ethiopian origin. Over several years, human and natural selection pressures together with exchange of genetic resources between cultivated and wild plants has resulted in the evolution of a diverse assemblage of cultivated types or landraces. Indigenous landraces are genetically diverse and well-adapted to climate change and they are indispensable for modern crop improvement efforts because of their tremendous value as a source of resistance to disease, pest, drought and other biotic and abiotic stresses. Conserving and maintaining valuable genetic resources is important, otherwise it would irreversibly be lost forever.

10.3.1 Role of community gene banks in sustaining agrobiodiversity

Community gene banks can contribute as local resources in rural development to secure seed for farmers to sustain agriculture for food security. Farmers often obtain germplasm for their own fields through an informal seed sector. Community gene banks are critically important to conserve the landraces among local farmers. Conservation of genetic resources within their locality keeps their natural evolutionary process, natural hybridization, mutation and production of new variants. Some farmers are capable of managing hybrid and improved seed production, and this will enable farmers to obtain higher incomes, but they have to take the risk of high inputs. Therefore, it is important to these farmers aware of the importance of agrobiodiversity management aspects.

10.4 Current situation and trends of the relationship of agrobiodiversity, climate variability and the role of local farmers

10.4.1 Food security in Ethiopia

Food insecurity remains an obstacle to development in Ethiopia (World Bank 1999).

Agriculture is the mainstay of the economy, but over two-thirds of rural households have less than 0.5 hectares of land, and most farmers are dependent on highly variable rainfall for agricultural production. To feed the ever increasing population, the domestic food availability has to be increased.

Even in years of bumper harvests, approximately 26 million Ethiopians do not produce enough food and income to meet their families' nutritional requirements (World Bank 1999). This is because land holdings are getting smaller as the population increases. Basic assets remain scarce as poor harvests force households to sell off some of their assets to purchase food, and farmers are increasingly purchasing, rather than growing their own food and some cases leading to migrating to urban areas for job opportunities. Another problem is that changing climate patterns and climate variability are leading to shorter and weaker short rainy seasons. Some farmers in the highlands are totally dependent on short rainy seasonal rains to plant short-cycle crops varieties that are harvested before the heavy rains and frost in July and August. But many more farmers plant their main, long-cycle crop during the short rainy season. If the short rainy season fails, these farmers are also forced to change from long-cycle to short-cycle crop varieties planted during the later rains. These short-cycle varieties produce far lower yields (Edwards and Egziabher 2000).

10.4.2 Farmers' development of resilient crop varieties

Many farmers are to adapt to climate change and coping with climate variability through innovative indigenous strategies. However, indigenous knowledge is getting eroded and should be documented and conserved as solutions to the Ethiopian food security lies in the hands of local farmers.

Crops cultivated by Ethiopian farmers have variable characteristics. The main cause of this variability is based on farmers' selection criteria. Farmers have different planting times, where the early maturing varieties are planted in April and the late maturing varieties in June, July, and August. The maturity date among crops is as short as 30–45 days while others

require 150–180 days. These variable characteristics of species reduce the risks associated with climate variability. Ethiopian farmers have an immense indigenous knowledge, such as agrobiodiversity management, prediction of rainy seasons, and selection of crop varieties and crop types. Subsistence farmers observe the onset of rainy season and also consider other variables as well to predict whether the rains are going to be heavy or light (Edwards and Egziabher 2000). More than 25 characteristics are used by farmers to select varieties (Alganesh 2008). Most of these have been used by women farmers (Ehsan et al. 2010). The selected characteristics have multiple factors of which adaptation to climate variability is the main factor. The most adapted crops to climate variability are teff, specific variants of barley and wheat, sorghum, maize, chickpea and finger millet.

Finger millet (*Elusine spp.*) originated from the highlands of Ethiopia and Uganda and is one of the most nutritious cereal crops. Finger millet can be used to in many local dishes, local alcohol brews, and as animal feed. It is high in starch and its proteins are more easily digested than those of wheat. It has the third highest iron content of any grain, after amaranth and quinoa. Finger millet is one of the drought tolerant crops grown in Ethiopia. Farmers have been securing their food and animal feed by growing finger millet when the rain is short and light. The finger millet varieties grown and conserved by the local farmers have excellent drought resistance properties. The long history of millet cultivation and its spread to different areas of the country is notable for extremely harsh farming conditions which has generated considerable genetic variability in this crop.

Sorghum (*Sorghum bicolor*) is also one of the drought tolerant crops grown in Ethiopia after finger millet. Sorghum is cultivated in many regions of Ethiopia, where its grains are used to make flat breads (injera), local beer, boiled grain and local soup. The grains can also be popped in a similar fashion to popcorn. Sorghum can be used as a source for making ethanol fuel, and may be better than maize or sugarcane in some environments, as it can grow under harsh conditions. The variability of Ethiopian sorghum has been well documented. In most regions, sorghum is planted in April and harvested after 180 days. One unique variety of sorghum in North Ethiopia that is extremely drought tolerant is planted in August and harvested after 150–180 days.

Teff is widely cultivated throughout Ethiopia as a staple cereal crop—is grown on 2.1 million ha or 32% of the total area and contributes 24% of the gross grain production. Teff can be

grown at altitudes of up to 2500 m above sea level. The Institute of Biodiversity Conservation expedition and collection database indicates that teff can also be grown at altitudes ranging from 800 m to 3200 m. It is widely adaptable and cultivated as an important crop in 10 out of 18 agro-ecological zones of Ethiopia (Kefyalew et al. 2000). It is grown over a wide range of agroclimatic conditions and a variety of soils from light sandy to heavy clay of variable fertilities. It grows well under difficult conditions, unsuitable for other cereal crops, and is considered a low risk crop. Its grain has high storage longevity under farmer's storage conditions. In 2010/2011 crop season, many superior cereal plants were affected by fungal disease. Teff grain has high nutritional value: high protein, carbohydrate, fat, vitamins A and C, fibre, thiamine, riboflavin, niacin, calcium, trace minerals and the essential amino acids.

Seven species of wheat have been found in Ethiopia (Vavilov 1951) of which pasta or macaroni and bread wheat exhibit the highest diversity. The country is endowed with many unique varieties of wheat as a result of the highly diverse agro-ecological conditions coupled with the farmer's selection criteria. These unique varieties are well adapted to climate change and variability. Based on farmers' knowledge, the purple seeded wheat is selected because of its wide adaptability to different climate factors. One characteristic that is valuable in adapting to climate variability is maturity date which varies amongst these different varieties of wheat. The existing varieties have been selected by farmers taking into account their flexibility to adverse climatic conditions and other factors. The varieties are also adapted to rainfall variability. Varieties with smooth, long and bended awn at maturity, for example, are more tolerant to heavy rains. Varieties with hairy glumes are tolerant to humidity and high heat. In general the varieties selected by farmers appear to be resilient to climate change.

Ethiopia has only one species of barley (*Hordium vulgare*) that exhibits high variability. Saesaa (a local name) is among those unique variants of the barley species. This variety is two rowed barley, famous in North Ethiopia (Tigray region) and uniquely adapted to rainfall variability. When there is enough rain during June it matures late and when the rain comes very late and for a short period of time it matures early.

In addition to cultivating climate change resilient crops and varieties, Ethiopian farmers deliberately practice mixed planting (planting several different crop species in one piece of land at a time). According to Edwards et al. (2000), farmers often insure themselves against

rainfall irregularity by planting a mixture of wheat and barley (locally referred to as ‘hanfets’). If the rainfall is heavy, it favours the wheat, and if it is light, the barley does better.

In the pastoral systems of southern Ethiopia, there is a shift to camel farming as a coping strategy. Southern Ethiopia receives insufficient rainfall and has a long history of devastating droughts leading to loss of livestock and vegetation. Camels are more suited to dry climate than cattle because they only need water every 10 days. In the past, camels have been used mainly for tracking, meat and milk production. Smallholder farmers and pastoralists also fulfil an invaluable role in conserving animal genetic diversity and developing livestock breeds that can make use of marginal environments under tough climatic conditions. But domestic animal diversity is being lost at an alarming rate as local livestock breeds are crossed or replaced with higher-yielding exotic breeds and habitats of pastoralists and their animals are steadily disappearing. Local livestock breeds are naturally resistant to many diseases.

10.5 Conclusions and recommendations

Small scale farmers are resilient and able to cope in harsh environments. Farmers are able to preserve the natural wealth of agricultural and grazing lands, soil, biodiversity, water and aquatic resources that they use in production. Their indigenous knowledge is an invaluable resource to conservation of agrobiodiversity. This knowledge should be harnessed to ensure that best practices for sustainable agriculture are developed and adopted, and thus protecting communities against shocks. The contribution of agrobiodiversity to food security cannot be over emphasized. There is need to ensure that agrobiodiversity is conserved and effectively managed diversity as many livelihoods in the country depend on these resources

Replacement of local varieties with improved or exotic varieties and species is the main cause of genetic erosion in crops. Policies and strategies to create opportunities for promoting and conserving indigenous crops are needed. In addition, it is critical to raise awareness of the close relationship between climate change, food security and agrobiodiversity. Conservation of agrobiodiversity should be an important component of climate change adaptation. A new understanding of appropriate conservation strategies for agrobiodiversity is necessary, by which in situ concepts play a leading role.

References

- Alganesh T. 2008. Morphological and molecular diversity of Ethiopian wheat from 10 regions of different agro ecological zone, thesis. Rome, Italy.
- Baumgärtner S. 2007. The insurance value of biodiversity in the provision of ecosystem services. *Natural Resource Modelling* 20: 87–127.
- Dercon S, Christiaensen L. 2007. Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. World Bank Policy Research Working Paper 4257. Washington DC: World Bank.
- Di Falco S, Chavas JP, Smale M. 2007. Farmer management of production risk on degraded lands: The role of wheat variety diversity in Tigray Region, Ethiopia. *Agricultural Economics* 36: 147–156.
- Edwards S, Egziabher TBG. 2000. Agrobiodiversity and coping with variability in weather and soils. Institute for Sustainable Development.
- Ehsan D, Alganesh T, Kassahun E, Basazin F, Tesfaye WS, Tesema T, Wilson M, Maarten Z, Xavier S, Imke T. 2010. The role of gene bank and indigenous knowledge in adapting climate change. Addis Ababa, Ethiopia: Institute of Biodiversity Conservation.
- FAO. 1999. The role of biological diversity in feeding the world.
- Kefyalew T, Tefera H, Kebebew A, Ayela M. 2003. Phenotypic diversity for qualitative and phenologic characters in germplasm collections of teff (*Eragrostis tef*). 73–80.
- Naylor R, Falcon W, Fowler C. 2007. The conservation of global crop genetic resources in the face of climate change. Summary statement from a Bellagio meeting held on September 3–7, 2007.
- The Development Fund. 2010. A viable food future, Part I. Oslo, Norway: The Development Fund.
- Unruh JD. 2004. The dilemma of African agrobiodiversity: Ethiopia and the role of food insecurity in conservation. Department of Geography, Indiana University.
- Vavilov NI. 1951. The origin, variation, immunity and breeding of cultivated plants Translated from the Russian by KS Chester. pp. 37–38. New York: Ronald Press.
- Van den Berg M, Kumbi GE. 2006. Poverty and the rural non-farm economy in Oromia, Ethiopia. *Agricultural Economics* 35(Suppl.): 469–475.
- World Bank. 1999. Entering the 21st century: The changing development landscape. World Development Report 1999/2000. Oxford University Press.

11. Mitigating impacts of climate change and climate variability on the livestock sub-sector in Ethiopia

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Abstract

The impact of climate change and climate variability on livestock resources and feed is a big concern. There is considerable variability and uncertainty in climate change projections and on the outcome of climate change and climate variability. Climate change will have far-reaching consequences on livestock production mainly arising from its impact on grassland and rangeland productivity. The indirect impact of climate change will be on water, feed, and fodder which are the most important inputs for livestock production. Compared to crops, much less is known about the effects of climate change on livestock, particularly in Ethiopia. This paper is a review of published literature, electronic articles available, and searches of databases on climate change and livestock in Ethiopia. The review of secondary data focused on Ethiopia, and supported with information from global sources. The existing knowledge and experiences in Ethiopia, and elsewhere, support the existence of impacts of climate change and variability on livestock production. In addition, there are adaptation and mitigation practices that can be documented and further explored. Adaptation practices include economic diversification, changes in feeding management, manure management and grazing management as well as control of invasive species in the rangelands. By maintaining the rangeland conditions, the grasslands can serve as a carbon sink and thus contribute to the diversification of ecosystem services.

Keywords

Climate change; climate variability; impact on livestock; adaptation and mitigation strategies.

11.1 Introduction

The supply and availability of food has been a crucial factor that has shaped the emergence, development and persistence of human civilizations throughout the ages (Thornton 2010). Global human population in 2050 is estimated to reach 9.15 billion and most of the increase will be in developing countries (UN 2009). There is variation in per capita consumption of meat (17.7 kg/year for developing countries and 81.6 kg/year for developed countries) and dietary protein contribution of animal products (22% for developing countries and 60 for developed countries) indicating substantial room for expansion of livestock production (Thornton 2010).

Livestock is among the fastest growing agricultural sub-sectors in developing countries (Steinfeld et al. 2006). Over the past 20 years, cereal, fish, meat and egg production in developing countries have increased by 78%, 113%, 127% and 331%, respectively, and this growth is driven by rapidly increasing demand for livestock products because of population growth, urbanization and increasing incomes (FAO 2010).

Livestock systems are significant and directly support the livelihoods of 880 million smallholder farmers in the developing world (FAO 2010). About 70% of the 880 million rural poor living on less than USD 1.00 per day are partially dependent on livestock for their livelihoods (World Bank 2007). Livestock production can be found on two-thirds of the global drylands (Clay 2004), while grasslands cover approximately 30% of the earth's ice-free land surface and 70% of its agricultural lands (FAO 2005).

With an estimated 34.6 million cattle, 24.9 million sheep, 18.7 million goats, 1.16 million camels and 8 million equine, Ethiopia's livestock has a lot of potential (MOARD 2000). The highlands comprise 40% of the country's land area, and hold 88% of the human population and 74% of Ethiopia's livestock. More than 90% of the croplands are cultivated using draft animals. In contrast, the lowland has 78 million hectares and 12% of the total human population. Estimates by MOARD (2000) showed the share of pastoral and agropastoral areas in terms of livestock ownership to be 28% cattle, 26% sheep, 60% goats and 100% camels.

Recent estimates of livestock contribution to agricultural GDP amounted to 45% (Behnke 2010). Livestock in the highlands depend on crop residues and agro-industrial by-products to supplement natural pasture. In the pastoral systems, however, livestock production is almost

totally dependent on natural pastures and browses. The impact of climate change and climate variability on livestock resources and feed is therefore an issue of big concern.

According to the Intergovernmental Panel on Climate Change (IPCC 2007), climate change and climate variability are real, and that they will become worse. While climate change is a global phenomenon, its negative impacts are more severely felt by poor people in developing countries who rely heavily on the natural resources for their livelihoods (IPCC 2007).

The key effects of climate change will be increased dryness and high temperatures, reduction in primary productivity, land use changes, animal disease, land degradation in some cases, changes in species composition (and thereby animal diets and feeding strategies), decreased livestock productivity, income and food security (Sere et al. 2008). Increased temperatures, for instance, are expected to cause additional loss of moisture from the soil, reduced and more intense rainfall and higher frequency and severity of extreme climatic events such as floods and droughts. These factors are already leading to loss of biological and economic productivity and putting dry land populations at risk of short and long term food insecurity (Elasha et al. 2005).

There is considerable variability and uncertainty in climate change projections and on the outcome of climate change and climate variability (IPCC 2001). Rural poor communities greatly rely on agriculture and livestock keeping for their survival, which are amongst the most climate-sensitive economic sectors. Climate change will have far-reaching consequences on livestock production, mainly arising from its impact on grassland and rangeland productivity. The impact of climate change is expected to increase the vulnerability of livestock systems and reinforce existing factors that affect livestock production systems.

For rural communities, losing livestock assets could trigger chronic poverty and have a lasting effect on livelihoods. The direct effects of climate change will include higher temperatures and changing rainfall patterns, which could translate into the increased spread of existing vector borne diseases and macro-parasites, accompanied by the emergence and circulation of new diseases (IFAD 2009). In some areas, climate change could also generate new disease transmission models (IFAD 2009).

Compared to crops, much less is documented about the effects of climate change on livestock particularly in Ethiopia. Furthermore, it is generally believed that the impacts of climate

change are likely to be highly spatially variable, impacting on ecosystems goods and services upon which poor people and livestock keepers depend, thus exacerbating current development challenges (Thornton et al. 2008). Due to lack of long-term and/or continuous meteorological records in many parts of the developing world including Ethiopia, as well as the lack of scientific projections at local scales, scientific information is often insufficient for analysing local exposure to climate change.

This paper is organized in three sections. The first section reviews the current situation and trends of the impacts of climate change on livestock production specifically in Ethiopia. The second section discusses the impact of climate change on livestock production and identifies the key vulnerabilities in highlands and pastoral systems. The last section identifies key points for developing adaptation and mitigation strategies.

11.2 Review of current situation and trends in Ethiopia

Literature on climate change and variability in Ethiopia has focused on the perceptions of the community regarding the impacts of climate on livestock production (Elias 2009, Senbeta 2009, SC-UK 2009). In very few cases, the community perceptions are supported with some meteorological data particularly rainfall and temperature.

A study on climate change impact on livelihoods, vulnerability and coping mechanisms of West-Arsi zone in Ethiopia by Senbeta (2009) showed that the trend of gradual and extreme weather change was particularly negative for the livelihoods of mid and lowlands of the West-Arsi zone, but positive in some places where agriculture was constrained by low temperatures. On the other hand, drought, delayed rainfall, erratic precipitation, and heavy and unseasonal rain are challenges to the livelihoods of the whole region. To cope with these impacts, communities use savings, diversification, changing growth season, mobility, selling of livestock, and selling of wood as strategies. Government institutions provide coping strategies such as awareness raising, credit, dissemination of technology and emergency aid. Though all households in the zone are vulnerable to climatic crises, the problem is more acute for the poor, landless, children, women, large-sized families, and pastoralists. Vulnerability is further exacerbated by unavailability and high prices of agricultural inputs, landlessness and unemployment, and water shortage. The study suggests a relentless need to address these challenges both through short and long-term policies.

A study on climate related vulnerability and adaptive capacity of Borana and Somali pastoralists in Ethiopia (SC-UK 2009), showed that the underlying drivers of vulnerability to climate change included environmental degradation, population pressure, conflicts, social and gender inequalities, inadequate non-pastoral employment opportunities and skills, poor access to infrastructure, resources and services, inadequate government policies, and the declining role of traditional social institutions.

A case study by Elias (2009) to identifying threats of climate change on pastoral production under restricted mobility in Ethiopia in Negalle, Yabello and Moyale sites showed that the average total annual rainfall was constantly declining in all sites, but more pronounced in the Negelle and Moyale sites. Extreme weather conditions such as longer and more frequent droughts have become a common phenomenon in the Borana area. Based on the study, elders from the pastoral systems stated that they have been experiencing an unusual variability in climate resulting in unpredictable rainfall and drought occurrences, leading to range degradation and drying up of water ponds. There were about three years of famine in every 7–8 years in the past, but in recent years droughts have become much more frequent.

Communities, government officials, and non-governmental agencies in Borana and Shinile zones have reported shorter rainy seasons during the last decade (Elias 2009). Rains tend to start late and end early. In addition, rainfall frequency, distribution, and predictability seem to have decreased in both areas. This has led to scanty or no pasture growth, increased water scarcity and depletion of resources. In Borana, it has led to increased competition and conflicts over pasture and water resources. According to local observations, temperatures in Borana and Shinile zones have increased significantly, consistent with scientific observations and projections for Ethiopia as a whole. Local observations of increasing dryness and reduced rainfall in the Shinile zone are consistent with slight decreases in rainfall for some months in the Shinile and Erer districts since 1995 (FEWS NET 2009, McSweeney et al. 2008).

A study by the Famine Early Warning System Network (FEWS NET) of drought tendencies in Ethiopia and equatorial sub-tropical Eastern Africa presents an analysis of Ethiopian rainfall from 1960 through 2004 from 186 gauges in Ethiopia and 373 gauges from surrounding countries (FEWS NET 2005). Substantial post-1997 declines in March–September rainfall have been observed in the northeast, southeast and southwestern parts of Ethiopia, a result corroborated by several independent data sources. The observed decreases

in rainfall have been resulted in an increase in millions of people in need of food aid. The greatest decrease has occurred during the March–May season, though the June–September rains have also decreased in many areas. This recent dryness may be linked to a warming tendency in the southern Indian Ocean, and is likely to impact densely populated and/or water-insecure regions of southern and eastern Ethiopia. Of most concern at the national level is the recent increase (1990–1996) and then decrease (1996–present) in the total March–May rainfall.

Regional time series data suggest variations from the above pattern, where the rainfall has been fairly constant over a period of time in northwest Ethiopia, with a decline in the mid-1980s followed by gradual recovery to the present. In the southwest of Ethiopia, there has been an overall decline in rainfall since the 1960s, with a steep drop occurring after 1996. From a food security perspective, the post-1980 decline found in the March–September southeast/eastern rainfall and the post-1996 decline in the northeast is of great concern.

11.3 Impacts of climate change and variability on livestock production

Detailed information on the impact of climate change on livestock production in Ethiopia is lacking, except for the case of drought. Nevertheless, the paper reviews the impact of climate change on livestock production in Ethiopia from the limited available information (FEWS NET 2005, Alemayehu et al. 2007, Senbeta 2009, Elias 2009, SC-UK 2009) and from other countries with similar ecosystems (Thornton et al. 2008, IFAD 2009). The impacts of climate change on the different components of livestock production are discussed below.

11.3.1 Water

Water scarcity is increasing at an accelerated pace and affects between 1 and 2 billion people globally (Thornton et al. 2008). Climate change will have a substantial effect on global water availability in the future. Not only will this affect livestock drinking water sources, but it will also have a bearing on livestock feed production systems and pasture yield (IFAD 2009).

The projections of the impact of climate change on water availability and quality in Shinile and Borana zones of Ethiopia showed that an increase in temperatures will likely lead to enhanced water evaporation rates, especially in Shinile, where temperatures are already very high, thereby leading to decreased water availability (SC-UK 2009). Most of the increase in annual rainfall in Borana is expected to occur during the short rainy season (September to

November), and the proportion of rain falling in heavy precipitation events is expected to increase in both zones. There are high uncertainties regarding the impacts of these changes on water availability and quality. A greater proportion of rain falling in heavy precipitation events might lead to more water lost as runoff, leading to less usable/available water, more soil erosion, and decreased soil water retention.

11.3.2 Animal feeds, feeding systems and rangelands

As climate becomes more variable, niches for different species change and this may modify animal diets and compromise the ability of smallholders to manage feed deficits (IFAD 2009). Changes in the primary productivity of crops, forage, and rangelands will depend significantly on location, system, and species. According to Thornton et al. (2008), in C⁴ plant species, a rise in temperature to 30–35° C may increase the productivity of crops, fodder and pastures. In C³ plants, rising temperature has a similar effect, but increases in CO₂ levels will have a positive impact on the productivity of these crops. For food-feed crops, harvest indexes will change, as will the availability of energy that can be metabolized for dry season feeding. In semi-arid rangelands where the growing season is likely to shorten, productivity is expected to decrease. Rising temperatures due to climate change will also increase lignification of plant tissues and thus reduce the digestibility and the rates of degradation of plant species.

The indirect impact of climate change focuses on water, feed and fodder which are the most important inputs for livestock production. Their overall and relative availability may be affected by climate change and this may be particularly crucial in rangelands. As livestock production in rangelands is mainly dependent on natural pasture and water, these will be crucial to the rangelands. A decrease in mean annual precipitation in Africa is expected to have a negative impact on the grasslands. However, an increase in water use efficiency resulting from CO₂ doubling is estimated to increase grass production by 20–30%, which could offset this negative effect.

² C³ plants, which account for more than 95% of earth's plant species, use an enzymatic reaction (via rubisco) to make a three-carbon compound as the first stable product of carbon fixation. C³ plants flourish in cool, wet and cloudy climates where light levels may be low, because the metabolic pathway is more energy efficient and, if water is plentiful, the stomata stay open and let in more carbon dioxide. Carbon losses through photorespiration are high. C⁴ plants possess biochemical and anatomical mechanisms to raise the intercellular carbon dioxide concentration at the site of fixation, which reduces, and sometimes eliminates, carbon losses by photorespiration. C⁴ plants, such as sugar cane, inhabit hot, dry environments and have very high water use efficiency, allowing up to twice as much photosynthesis per gram of water as in C³ plants, but C⁴ metabolism is inefficient in shady or cool environments. Less than 1% of the earth's plant species can be classified as C⁴.

A temperature increase is also expected to have a positive effect on the amount of grassland as forests shift to grasslands. The effects of climate change on grassland systems are potentially complex with the effects on forage yields and quality which may affect the relative suitability of grasses and legumes and their utilization (Wu and Topp 2008). Grazing has significant impacts on the biophysical properties of land surfaces and assessments of the compatibility of grazing with livestock production must explore the potential for interactions between climate change and grazing regimes (Gerlanc and Kaufman 2003). One of the major greenhouse gas emission contributions from livestock production is from forage or feed crop production and related land use (Goodland and Anhang 2009).

Grasslands or rangelands are mainly grazed by ruminant and ruminant-like (camelids) livestock species. A unique property of these species is their ability to convert cellulose, hemicelluloses and non-protein nitrogen to useful animal products, which is achieved by the microbial fermentation in their fore stomach. Fermentation or rumination, however, is associated with production of methane (CH₄), which not only represents a waste of feed energy, but CH₄ is also a powerful greenhouse gas. Ruminants are the single most important sources of CH₄ emission and global enteric CH₄ emissions from managed grasslands have been estimated to account for 44 Tg/yr (Clark et al. 2005). In grazing systems, the most important factors influencing CH₄ yield include feed intake, animal species, botanical composition and plant maturity, and management interventions.

Tropical plant species are not only less digestible than temperate species, but they contain large amounts of more methanogenic plant constituents (cell wall) than temperate species. In addition, the livestock species found in tropical environments have evolved by developing physiological, structural and behavioural adaptations to counter environmental stresses and highly fluctuating feed resources. Prolonged retention in the fore stomach of fibrous feeds to extract the maximal amount of energy would appear to be the strategy adopted by species adapted to the feed-scarce tropical environment (Pinares-Patino et al. 2003). Thus, it would be expected that CH₄ yield from livestock in tropical environments be higher than in temperate environments. Animal husbandry practices result in methane emissions, and the two sources of emission are through the enteric fermentation (the digestive processes of animals) and via manure management. Enteric fermentation emission is derived principally from the quality and quantity of feed consumed by ruminants (Berhanu 2006). The estimated total amount of

methane emission from enteric fermentation in Ethiopia in 1994 was about 1337 Gg (Giga Gram), accounting 80% of the total national emission. Livestock manure used as a fuel releases about 49.5 Gg of methane per annum, because of combustion (NMSA 2001).

Livestock activities contribute 18% of total global anthropogenic GHG emissions (including deforestation for grazing land), which is more than the contribution from transport. Livestock is the single largest anthropogenic user of land globally (FAO 2006) and accounts for 9% of anthropogenic carbon dioxide emissions, most of which is due to the expansion of pastures and arable land for feed crops. It generates even bigger shares of emissions than other gases with greater potential to warm the atmosphere. Feed prices have remained high as the effect of climate change has negatively impacted on world feed grain production with decreased crop yields in many regions. Accordingly, improvement in production, management and utilization of feed resources as related to climate and other socio-economic changes are very important for livestock production (Goodland and Anhand 2009).

An environmental impact assessment carried out by NMSA (2001) using climate change scenarios in Ethiopia considered incremental scenarios by assuming a 2°C and 4°C increase in temperature with change of $\pm 20\%$ and $\pm 10\%$ and no change in rainfall over and above the 1961–1990 mean. Based on the temperature incremental scenario, the impact of climate change was analysed for wheat in the highlands of Ethiopia, and the result showed that the United Kingdom Meteorological Office-1989 I (UKMO) and Geophysical Fluid Dynamics Laboratory's (GFDL R-30) models projected a decrease in crop maturity period (ranging from -10.6% to -18.5%). Decreases in yield were also predicted by the above two models. The decrease in yield might be associated with an increase in temperature that may significantly shorten crop development stages. The yield decrease for wheat had a direct and indirect implication on livestock development. The direct impact is that wheat-short and wheat bran (by-products of wheat milling) contribute as major constituents in feed composition of concentrate feeds in Ethiopia. Under the current market price, concentrate feed has increased by 25% compared to 2006 base price (Alemayehu et al. 2007), and there is also an anticipated decrease in wheat yield because of incremental climate change scenario, and this may elevate the price of concentrate feed. Wheat straw is a major crop residue fed to livestock in the Ethiopian highlands (IPMS 2004), and since grain yield and straw quantity are positively

correlated, a decrease in grain yield consequently results in a reduction of straw quantity, which aggravates feed shortage (Alemayehu et al. 2007).

Climate is a critical element to rangeland management. Among the climatic factors, precipitation is the most important single factor determining the type and productivity of vegetation in a particular area (Holecheck et al. 2004). Climate change impacts on pastoralism and agriculture are therefore highly site specific, along with type of livestock and crop. For example, while elevated atmospheric carbon dioxide levels may augment crop productivity, higher temperatures may offset such benefits by increasing pest and disease outbreaks (Fischer et al. 2002). In countries like Ethiopia, however, where dry land pastoralism and rain-fed agriculture predominate, the productivity of livestock, pasture and crop species, which are already near their maximum temperature and drought tolerance, is expected to decrease, even with minimal increases in temperature (IPCC 2001).

11.3.3 Changes in species composition

As temperature and CO₂ levels change, optimal growth ranges for different species also change. Species alter their competition dynamics, and the composition of mixed grasslands changes (IFAD 2009). Higher levels of CO₂, for example, will affect the proportion of browsing species. The species are expected to expand as a result of increased growth and competition between each other. Legume species will also benefit from increases in CO₂ and in tropical grasslands the mix between legumes and grasses could be altered (IFAD 2009).

11.3.4 Biodiversity (genetics and breeding)

According to Goodland and Anhang (2009), the loss of genetic and cultural diversity already occurring in agriculture as a result of globalization will also be evident in crops and domestic animals. An increase in global temperature of 2.5°C would determine major losses: between 20 and 30% of all plant and animal species assessed could face a high risk of extinction (Thornton et al. 2008). Ecosystems and species display a wide range of vulnerabilities to climate change, depending on the imminence of exposure to ecosystem-specific critical thresholds. However, assessments of the effects of CO₂ fertilization and other processes are inconclusive (Thornton et al. 2008). Local and rare breeds could be lost as a result of the impact of climate change and disease epidemics (Thornton et al. 2008).

Biodiversity loss has global health implications and many of the anticipated health risks driven by climate change will be attributed to loss of genetic diversity. According to a study by NMSA (2001), there is spread of malaria into highland areas, which have never experienced it before; loss of biodiversity and a decline in wildlife numbers have also been observed in Ethiopia due to climate change, increased variability, and other associated factors.

11.3.5 Livestock health

Climate change is expected to affect disease and pest distribution, range, prevalence, and seasonality, but the degree of change remains highly uncertain (IPCC 2007). The potential impact of climate change on human diseases is relatively better understood than impacts on animal health (IPCC 2007). Heat stress and drought are likely to have further negative impacts on animal and human health and disease resistance (IPCC 2007). Climate change would affect the distribution and incidence of animal and plant diseases (NMSA 2001).

Trypanosomiasis, which used to be a lowland livestock disease in Ethiopia, for instance, has recently started to spread to adjacent highland areas due to ecological warming (Alemayehu et al. 2007). In general, microorganisms including viral, bacterial and fungal agents that are fatal to animal and forage crops take advantage of climate change (changes in temperature, humidity) to perpetuate themselves and threaten the existence of livestock (Thornton et al. 2008). The biological mutation of these agents enhanced by a favourable environment could worsen the situation.

Current climate variability and drought are major challenges for the livestock sector. Hence, the biodiversity in their natural habitat would be in jeopardy (Cunningham 1995, Alemayehu et al. 2003). A case study by Save the Children-UK (2009) in Borana and Shinile zones shows that although the use of vaccinations and medications have decreased the incidence of livestock diseases in some of the areas, disease and pest outbreaks were still mentioned as important hazards in the zones. In Shinile, for example, the occurrence of strange or uncommon livestock diseases was reported. The strange livestock diseases are attributed to a combination of weather patterns and decreased disease resistance, the latter stemming from decreased pasture availability and quality, as well as increased water stress (SC-UK 2009).

11.3.6 Impacts on financial resources

The main financial resources upon which livestock keepers depend on include livestock and livestock products, crops, savings, credit and cash. Most of these resources are directly dependent on climate-sensitive natural resources such as pasture, farmland and forests, implying that these communities' financial resources are strongly impacted by drought. Drought leads to decreased pasture and water availability, which in turn leads to livestock emaciation and death, reduced livestock productivity (in terms of milk and meat), reduced resistance to diseases, more livestock being sold at lower prices, thereby leading to weaker terms of trade, and decreased household incomes.

Many pastoral and agropastoral communities in Borana and Shinile zones have expressed concerns that income generated through livestock sales is no longer sufficient—compounding poverty, food insecurity, and pastoralist dropouts (SC-UK 2009). A similar situation was observed in a pastoral dropout study in Borana Plateau (Gebru and Desta 2010). Results from a portfolio analysis that considered 17 years of cattle population dynamics (1980–97) in Borana demonstrated risk mitigation and food security benefits of including non-pastoral investments, such as savings and credit facilities, along with cattle (Desta 1999).

11.3.7 Livestock numbers and herd composition in relation to drought

Species diversification, spatial segregation of herds, and herd dispersal over a wide range of grazing lands and social networks are the most commonly used mechanisms to spread and mitigate risks of food insecurity in pastoral systems in Ethiopia. By segregating herds according to age and sex, and spreading them over accessible areas, pastoralists are able to derive the maximum use of available grazing resources (Desta and Gebru 2003). Significant losses due to drought are no exceptions in pastoral areas of Ethiopia. Between 1980 and 2000, the Borana suffered three major droughts in which pastoralists lost between 35–67% of their livestock with an estimated value of hundreds of millions of USD (Desta and Coppock 2002, Shibru 2001). Cattle population dynamics for 17 years (1980–97) exhibited a downward trend in cattle holdings per household as well as a “boom-and-bust” cycle (Desta and Coppock 2002). On average, households reportedly lost 67 head of cattle to drought-related mortality over 17 years, largely due to starvation (Desta 1999). Death losses were 10 to 15 times greater than net sales, indicating that natural factors and not marketing regulated the herd population size. The 2006 drought in Borana led to the death of 25–60 % of all livestock in the area,

while the 2008 drought caused the death of weak animals and some calves, and also impeded pasture and crop growth (SC-UK 2009). The worst years in the Somali region, in terms of drought, were 2007 and 2008, with communities reporting losses of about 80% of their cattle, 70% of their sheep, 40% of their camels and 30% of their goats. This shows that different livestock types have different resilience to climate hazards and livestock losses may be in part related to the amounts and distribution of rainfall. Communities in Shinile also mentioned that high temperatures foster the replacement of grass species by bushes, thereby contributing to enhanced bush encroachment.

According to the perceptions of the communities (SC-UK 2009), the impact of climate change, combined with other environmental degradation, demographic pressures, and increasing poverty stresses, may lead to a decrease in livestock populations in Shinile over the longer-term, although periodic population booms and busts will likely persist. Some breeds of livestock may not cope well with extreme heat and could suffer high mortality due to increased incidences of weather-related diseases. More frequent, longer and intense droughts could also lead to increased mortality. Inadequate access to veterinary services would undoubtedly exacerbate these impacts. This, coupled with the deteriorating role of traditional social institutions that used to support livestock recovery, would reinforce the cycle of poverty and livelihood vulnerability to climate change.

Reduction in household incomes resulting from decreasing livestock numbers could be prevented or minimized by changing livestock composition and by introducing new alternative income generating activities. In the Borana zone, the frequency of livestock population fluctuations may increase. Like in the Shinile zone, higher livestock mortality may occur due to an increase in average temperatures, as well as further bush encroachment. In addition, an increase in heavy rainfall events could result in an increase in periodic flash flooding, leading to more livestock deaths from drowning and water borne diseases. It is possible that livestock numbers will regenerate due to the availability of water and abundant pasture after flood waters recede. However, the impact of increased rainfall on livestock (especially during the short rainy season from September to November) is highly uncertain and will depend on the intensity of rainfall and on the capacity of communities to use and benefit from the increased rainfall. In both zones, it is likely that there will be shifts in herd composition. Pastoralists in Shinile zone are already shifting to goats and camels, instead of

cattle and sheep. This trend is likely to continue. Cattle species such as Zebu may also be favoured over other cattle species. The same is likely to happen in the Borana zone where, although cattle are still considered more valuable, some pastoralists have also begun to rear camels in addition to sheep and goats.

11.3.8 Pastoral livelihood

Climate change is affecting the drylands and pastoral livelihoods (Georgis 2010). The amount of rainfall determines the quantity, quality and the spatial and temporal distribution of natural pastures. Given the variability of rainfall, there is going to be increasingly scarce, scattered and unpredictable pasture. In addition, there are also non-climatic factors like demographic factors and conflicts. Because of conflicts, access to pasture will become more difficult leading to loss of livestock and livelihoods.

There is evidence that pastoralists are likely to diversify their livelihoods both within the pastoral system (for instance, increased reliance on camels in the Borana plateau, and the shift in species composition from grazers to browsers) and out of the system. Some who are forced to diversify out of the system are those that exited the system painfully, and do not have the skills or resources required to support a shift in livelihoods.

A large number of pastoral “drop-outs” are leaving the pastoral system every year, ill-prepared for a change in livelihoods (Gebru and Desta 2010). Borana and Shinile zones may see an increase in the number of pastoralist drop-outs in the future, as communities explore and increasingly engage in other income-generating activities that are less sensitive to climate hazards (SC-UK 2009). Such activities include wage labour and the establishment of viable cottage industries and businesses. Consequently, the number of livestock per household could continue to decrease in these areas. The effectiveness and sustainability of these alternative income generating activities will greatly depend on changes in literacy levels, education and technical training, and on support from NGOs and government agencies. NGOs in the Borana and Shinile zones are already promoting alternative income-generating activities, but many of these activities are still often climate-sensitive. It has been argued that risk management strategies are needed to assist the pastoralists to mitigate the situation and break the vicious cycle of poverty and food insecurity. One approach has been to encourage them to diversify investments to include non-livestock options and promote wealth conservation and human

capacity building so that the people can better protect themselves against economic and ecological shocks (Desta and Gebru 2003).

11.4 Developing adaptation and mitigation strategies

There are several responses to climate change: adaptation—which is the reduction in the vulnerability of livestock, people and ecosystems to climatic changes, and mitigation— which is about reduction in GHGs. Reducing the level of emission of GHG which contributes to global warming and supporting local communities in dealing with the impacts is key.

Livestock can play an important role in both mitigation and adaptation and has the potential to support the adaptation efforts of poor communities. In general, livestock are more resistant to climate change than crops because of their mobility and access to feed. However, it is important to note that the capacity of local communities to adapt to climate change and mitigate its impacts will also depend on their socioeconomic and environmental conditions, and on the resources they have available (FAO 2009).

Adaptive capacity is often determined by a range of factors, processes and structures such as income, literacy, institutional capacity, social networks, as well as access to information, markets, technology, and services (IPCC 2007). Given limited availability of these resources and services in many developing countries, especially in Ethiopia, adaptive capacity in the face of climate change is low compared to developed countries.

11.4.1 Livestock adaptation strategies

Livestock producers in Ethiopia have traditionally adapted to various environmental and climatic changes by building on their in-depth knowledge of the environment in which they live. However, increasing human population, urbanization, environmental degradation and increased consumption of animal foods have rendered some of those coping mechanisms ineffective (Sidahmed 2008).

Projected changes in the current climate and its variability would have serious implications on the natural resources, economy and welfare of Ethiopia (NMSA 2001). In addition, changes brought about by global warming are likely to happen at such a speed that they will exceed the capacity of spontaneous adaptation of both human communities and animal species.

However, studies in Ethiopia (McSweeney et al. 2007, SC-UK 2009, Senbeta 2009, Elias

2009) and several other studies (FAO 2008, Thornton et al. 2008, Sidahmed 2008, IFAD 2009) have identified ways to increase adaptation in the livestock sector.

Diversification, intensification and/or integration of pasture management, livestock and crop production

Livelihood diversification outside pastoralism is also used as a coping strategy to climate change. It is evident that the pastoral system is under a process of transformation as more and more people shift towards farming and diversification of economic activities outside pastoral production. All interviewed communities in Borana and Shinile zones seemed to agree that the diversification of financial resources and income-generating activities are key to adapting to changing climatic conditions, whether this means engaging in petty trade, sale of fuelwood and charcoal, construction and renting of houses, honey and alcohol sale, business creation and management, or learning to save money through financial institutions. In pastoral areas of Ethiopia, efforts must be made improving hay making, collection and preservation to prepare for adverse conditions or drought periods.

Climate and land availability provide a good opportunity for forage production. In Ethiopia, most improved tropical species can be grown in the lowlands (1500–2000 meters above mean sea level) and temperate species grow in altitudes ranging from above 2100 meters up to 3000 meters above mean sea level. Greater use of leguminous fodder trees and shrubs assists in increasing soil fertility, controlling soil erosion and providing fuelwood and timber. These legumes are well adapted to the current edaphic and grazing conditions; can be readily integrated into farming systems and retain their feeding value through the dry season; and show great success in the higher potential areas of the country. Conventional methods of establishing pasture are tedious and labour demanding, especially in the highlands. The low-cost methods such as backyard, under-sowing and over-sowing are better options and are more attractive to farmers.

There are also considerable opportunities for the use of fodder tree legumes through agroforestry. Currently, arable farming is expanding at the expense of traditional grazing land. This is putting pressure on grazing resources resulting in inadequate feed resources for livestock both in terms of quality and quantity (Geleti et al. 2001). Under these situations, development of integrated forage-cereal-livestock systems offers a method of accommodating and improving both crop and livestock production systems. Integration of forage legumes into

the cereal based cropping systems is one of the alternative strategies (Mohamed-Saleem 1985). This approach also enhances efficient utilization of land, labour and other inputs. Forage legumes fix nitrogen thus enhancing soil fertility (Geleti et al. 2001) and improve cereal yields when used as green manure (Abebe 1998). This strategy also improves the yield and nutritional value of harvested crop residues that can be used as feed resources particularly after grain harvest (Mohamed-Saleem 1985).

The potential dry matter (DM) yield of Napier grass surpasses that of other tropical grasses (Assefa et al. 2002), which is the main reason for its popularity among dairy farmers in Kenya, who need to maximize production per unit area of land. Berhanu (2006) found that methane production (g/d) for cattle fed on grass hay (185.7 ± 13.6) was higher ($p < 0.05$) than that for cattle fed on both teff straw supplemented with concentrate mixture (141.8 ± 13.6) and Napier grass (124.1 ± 13.6). Therefore, the potential of Napier grass for tropical ruminant feeding is high in terms of the feed quality and reducing methane emissions. In urban and peri-urban areas, the cost of milk production is high. Livestock feed, particularly roughage, which is the most important factor, hampers livestock productivity in general and milk production in particular (Mekasha et al. 1999). Rural-urban linkages are an important strategy to improve the supply of roughage to urban dairy farmers, and there are rural farmers that are able to produce forages from irrigated lands (Alemayehu et al. 2007). Planting early maturing crops to diversify income and food sources are also important for the community.

Breeding strategies (community-based breed improvement)

Although local breeds are adapted to harsh living conditions, developing countries are usually characterized by lack of technology in livestock breeding and agricultural programmes that might otherwise help to speed adaptation. Adaptation strategies address not only the tolerance of livestock to heat, but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann 2008). Such strategies could include identifying and strengthening local breeds that have adapted to local climatic stress and feed sources, and improving local genetic resources through cross-breeding with heat and disease-tolerant breeds. If climate change is faster than natural selection, the risk to the survival and adaptation of the new breed is greater. The high cost of purchasing an improved breed—even when they are available—is one of the challenges for development of the dairy sector in Ethiopia (Alemayehu et al. 2007). Artificial insemination (AI) services are at their infant stages, and

delivery is constrained. Therefore, facilitating provision of improved breeds in the highlands through community-based breeding programmes such as bull stations is considered a potential solution to facilitate difficulties of supplying improved breeds (IPMS 2004).

Market responses

Although Ethiopia is rich in livestock resources, inadequate market infrastructure, lack of market information systems, absence of market-oriented livestock production systems, inadequate numbers of exporting firms with low capacity, inadequate knowledge of international trade, low levels of quarantine facilities and procedures, prevalence of various diseases, repeated bans, cross-border trade and stiff competitions are the major challenges that hinder livestock trade in Ethiopia (Hurrissa and Eshetu 2003). The development of effective and efficient livestock marketing systems is essential to improving and sustaining the livelihoods of poor (and other) livestock producers in Ethiopia (Halderman 2004). In general, agricultural marketing could be enhanced by promoting interregional trade and credit schemes. In pastoral areas of Ethiopia, promoting marketing in normal times and supporting marketing in times of crisis are key entry points, and effective strategies need to be developed. Planned re-stocking is also recommended, especially for those who have lost their livestock.

Livestock technology innovations for adaptation

The focus of options for livestock technology innovations is on livestock production and marketing in order to satisfy a growing demand without damaging the environment. Those intervention areas already have been initiated such as pasture development, breed improvement, marketing, crop residue chemical treatment, urea molasses block, and commercialization of green forage production are considered as options to reduce the use of natural resources per unit of product produced. Adaptive measures for livestock-ecosystem balance should also integrate land husbandry with forage development.

Such innovation must be based on recommendations that from local, national and international experiences including lessons from government and non-government organizations, results of scientific findings, experience of community-based organisations, local knowledge, and review of the lessons from other countries. Great caution is needed, however, on adopting agriculture practices and techniques for climate change mitigation. Policy makers should not assume that solutions to climate change are necessarily technical, some of the solutions are social and cultural.

Capacity building for livestock keepers

There is a need to improve the capacity of livestock keepers and herders to understand and deal with climate change through increasing awareness. In addition, training in agro-ecological technologies and practices for producing and conserving fodder improves the supply of animal feed and reduces malnutrition and mortality in herds.

Livestock management systems

Efficient and affordable adaptation practices need to be developed for the rural poor who are unable to afford expensive adaptation technologies. These technologies include provision of shade and water to reduce heat stress from increased temperature, and reducing livestock pressure on rangelands through establishing and supporting normal time marketing. There are excellent examples of supporting normal time marketing in the Borana lowlands and also on market linkages to enhance engagement of pastoralists in export markets.

Modifying livestock diversity, composition and numbers

Increasing livestock diversity and adjusting herd composition towards fewer grazers (cattle and sheep) and more browsers and drought-tolerant species (such as camels and goats) were among the adaptation strategies suggested by pastoral communities in Ethiopia. In urban and peri-urban dairy farms, the proportion of cows out of the entire dairy herd is estimated at 50% and the share of milking cows out of the total herd is 36% (Mekasha et al. 2002). The national average proportion of cows in the entire herd is reported to be 42% (Tegegne and Gebrewold 1997). The higher proportion of cows in the total herd, in peri-urban and urban areas, is not surprising given that the peri-urban dairy production systems are market-oriented. Milk sale is the major income for these farmers (Mekasha et al. 2002). Oxen are widely considered to be the most important domestic animals in the Ethiopian highlands, as oxen perform nearly all the traction for cultivation. The reliance on oxen for draught purposes in many highland areas leads to differences in the cattle herd composition between highland and pastoral areas, and between different zones in highland regions.

11.4.2 Mitigation of livestock GHG emissions

The capacity of natural and human systems to adapt to climate change will be in jeopardy if mitigation measures are not taken up (IFAD 2009). Given the magnitude of the challenge to reduce the contribution of different factors to climate change, it is imperative for all sectors with significant mitigation potential to contribute to reducing GHG emissions (IFAD 2009).

Since agriculture has been recognized as a sector with such potential, farmers, herders, ranchers and other land users should be part of the solution (IFAD 2009). Therefore, it is important to identify mitigation measures that are easy to implement and cost effective in order to strengthen the capacity of local actors to adapt to climate change (Thornton et al. 2008).

Livestock production system contributes to global climate change directly through production of greenhouse gases. There are three main sources of GHG emissions in the livestock production system: enteric fermentation of animals, manure (waste products) and production of feed and forage (field use) (Dourmad et al. 2008). Indirect sources of GHGs from livestock systems are mainly attributable to changes in land use and deforestation to create pasture land. In Ethiopia, for example, most of the destruction of the natural vegetation in the highlands is because of conversion of forest and grazing land to cropland. In general, smallholder livestock systems (like the case within Ethiopia), have a smaller ecological footprint than large-scale industrialized livestock operations. Mitigation of climate change in the livestock sector can be achieved through various strategies as briefly discussed in the following sections.

Animal feeding management

The composition of feed has some bearing on enteric fermentation and the emission of methane, CH₄ from the rumen or hindgut (Dourmad et al. 2008). The volume of feed intake is related to the volume of waste product and the higher the proportion of concentrate in the diet, the lower the emissions of CH₄ (Goodland and Anhang 2009). Improving livestock efficiency in converting energy from feed into production can reduce losses through waste products. Increasing feed efficiency and improving the digestibility of feed intake are potential ways to reduce GHG emissions and maximize production and gross efficiency, as is lowering the number of heads. All livestock practices—such as genetics, nutrition, reproduction, health and dietary supplements and proper feeding (including grazing) management—that could result in improved feed efficiency need to be taken into account. In general, change of feed composition is helpful in increasing livestock productivity by reducing pressure on land, methane, and nitrogen emission. Therefore, alternative ways of improving livestock feed to satisfy the growing demand for animal products without disturbing the environment should be sought, but with efficient utilization of available resources. Although problems associated with the management of feed crop production is not a major problem in Ethiopia, there is a

need to be careful, particularly in the intensive livestock production system, as it can be the major source of GHGs emission in the future. Furthermore, there is a likely increase in intensive livestock production, particularly in the highlands of Ethiopia in the future. Intensification of livestock production should go hand in hand with efficient management of the environment.

11.4.3 Manure management (collection, storage, spreading)

One of the useful contributions of livestock is the provision of manure as a recyclable organic matter in mixed crop-livestock and pastoral farming systems. In addition to adding macro and trace minerals into the soil, organic materials can improve soil texture, increase absorption of moisture, improve water infiltration, increase soil aeration, reduce runoff and prevent crusting of the soil surface (Kumsa et al. 2004). In some highland areas, where the population is very poor and alternative sources of energy are very limited, people cannot afford to use livestock manure as organic fertilizer. Instead, the poor use and/or sell the dried manure (dung) as a source of fuel (Halderman 2004). Kumsa et al. (2004) reported that, although farmers in the central highlands of Ethiopia have different ways of storing manure, cleaning the barn every day and adding fresh dung to a pile stored under the open sun is the most prevalent method of storage. Lekasi et al. (1998) reported that manure stored under the open sun is of poor quality and environmentally unsafe. Despite its value as organic fertilizer, manure can also be regarded as a waste and source of air and water pollution in places of overproduction, when improperly used and stored (Brandjes et al. 1996). Therefore, improved manure management will be important for sustainable utilization. Improving the management of animal waste products through different mechanisms, such as the use of covered storage facilities is also important. The level of GHG emissions from manure (CH_4 and N_2O) depend on the temperature and duration of storage. Long-term storage at high temperatures results in higher GHG emissions. In the case of ruminants, pasture grazing is an efficient way to reduce CH_4 emission from manure because no storage is necessary.

11.4.4 Grazing management

One of the major GHG emission contributions from livestock production is from forage or feed crop production and related land use. Proper pasture management through good grazing management, like rotational grazing, would be the most cost-effective way to mitigate GHG

emissions from feed crop production. Animal grazing on pasture also helps reduce emissions attributable to animal manure storage. Introduction of grass species and legumes into grazing lands can enhance carbon storage in soils.

11.4.5 Pasture rehabilitation and control of invasive species

According to PADS (2004), about 51% of the rangelands in Ethiopia are under poor conditions, justifying the need for rehabilitation. Rangeland rehabilitation and reviving traditional range management practices have improved rangelands. Furthermore, different encroaching woody species and other invasive plants like *Prosopis juliflora* and Parthenium are widespread in Ethiopia and require appropriate control methods. Exotic plant species have been purposely and/or accidentally introduced throughout the world due to their economic, environmental or aesthetic values. Nonetheless, introduction of new species is not always a success as some of the new species may be invasive with negative impacts (economic, environmental and social). Parthenium weed (*Parthenium hysterophorus*), prosopis (*Prosopis juliflora*), water hyacinth (*Eichhornia crassipes*), cactus (*Euphorbia stricta*) and lantana weed (*Lantana camara*) have been identified by the Environmental Policy and the National Biodiversity Strategy and Action Plan as major threats to the biodiversity of Ethiopia and economic well-being of its people (Tessema et al. 2009). Encroachment of rangelands by invasive species, reduction of crop yield, genetic erosion of biodiversity, disruption of water flow, poisoning of livestock, and formation of impenetrable thickets are some of the impacts of invasive species across a wide range of agro-ecologies (Gebru 2008).

Weeds are major problems in both perennial and annual pasture and forage crops and unless they are controlled, productivity will be low. Though different weed control methods like herbicides, machine mowing and topping have been tried in Ethiopia, hand weeding has been found to be the best, particularly in smallholder systems. Since family and hired labour is plenty and cheap, there is an opportunity to use it for weed control, creating a considerable opportunity to foster development of improved pasture and forage crops on a large scale without a major problem of weed infestation.

11.4.6 Livestock grazing and soil carbon sequestration

Experts have estimated that soil contains twice the quantity of carbon than is in the atmosphere and demonstrated that enhancing soil carbon sequestration could make a

potentially useful contribution to climate change mitigation (FAO 2009). Considering the importance of rangelands in land use (accounting for about 40% of the total land surface area), herders and pastoralists can play a crucial role in soil carbon sequestration. Rangelands account for about 57% of the total land area (PADS 2004) in Ethiopia, with an enormous potential for carbon sequestration. Georgis (2010) examined the effects of degradation as well as soil depth on the soil seed bank and its implication on carbon sequestration and climate change in Allalidege rangeland of zone three of Afar region. The results show that good and enclosed sites had higher (2.03 ± 0.26 and $1.93 \pm 0.41\%$, respectively) organic carbon (OC) content in the 10–20 cm soil depth, while fair, poor and very poor sites had higher (2.10 ± 0.22 , 1.90 ± 0.41 and 1.90 ± 0.45 , respectively) OC content in their shallower depth (0–10 cm). Average organic carbon density was about 2.04 g cm^{-3} , and an average of 1.22 Gt carbon was sequestered in the top 30 cm of the rangeland. In addition, the study revealed that the potential contribution of rangelands to carbon sequestration is so immense that they can be considered climate change mitigation programmes.

Grazing can have either a positive or negative impact on rangeland vegetation and soils, depending on the climatic characteristics of rangeland ecosystems, grazing history, and effectiveness of management (Milchunas and Lauenroth 1989). Common grazing management practices that can increase carbon sequestration include stocking rate management; rotational, planned or adaptive grazing; and enclosure of grassland from livestock grazing. Rangelands are estimated to store up to 30% of the world's soil carbon in addition to substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses (White et al. 2000, Grace et al. 2006). Improved management of these resources is a matter of priority, thereby significantly increasing the potential of these grasslands to sequester carbon (FAO 2009). Improved management practices include restoring organic matter to soils, reducing erosion, and decreasing losses resulting from burning and overgrazing. The capacity to sequester carbon depends on the climatic zone, past history, and the status of the land resources such as soil and vegetation, and the opportunities available to change management practices (management techniques, competition with other land uses, economic tradeoffs, land tenure, social organization, incentives and political will).

11.4.7 Essential points needed for development interventions

To ensure sustainable and more efficient livestock production, collaborative research efforts and finding positive ways to deal with public perception of the livestock sector are crucial. The present high prices of feed and effects of climate change offer an opportunity for scientists, academicians, policy makers and private sector representatives (feed, poultry and livestock industries) to look at past and present research on feed production and utilization and chart out a way forward. There is need to explore new ideas and come up with practical, effective and economical suggestions for feed substitution, enhancing feed efficiency, and sustainable livestock production (Alemayehu et al. 2007). Furthermore, collaborative management of natural resources is very important. Participatory approaches to sustainable management of land, forest and natural resources are essential to developing long-term sustainable strategies. Decision making processes should be inclusive of all relevant stakeholders (farmers, pastoralists, herders). Furthermore, reducing conflicts over available resources needs to be undertaken in the Ethiopian pastoral areas.

Successful adaptation strategies require involvement of the communities in identifying new solutions to ensure long-term sustainability of interventions. Also, adaptation strategies need to take into account cross-cutting issues (e.g. environment, health, and social factors such as increased migration and conflict). Proper risk management mechanisms and preparedness measures need to be put in place to cope with the impacts of more frequent and extreme climatic events (IFAD 2009). Preparedness measures, early warning systems and other risk coping strategies (e.g. strengthening infrastructure, insurance systems and forecasting) are needed to reduce the impact of severe weather events and prevent loss of livestock.

Information about climate change is a crucial component of adaptation. It is important to ensure that knowledge is shared with local communities. An understanding of the patterns of variability of current and projected climate and seasonal forecasts is essential in anticipating shocks and losses, and in enabling external agencies to provide targeted assistance to herders. Overall improvement in education, savings and access to credit, and in establishing community groups in Ethiopia are very essential. Capacity building of community members on reforestation, rangeland management, and enclosures are also a matter of priority.

Efforts to support mitigation should focus on reforestation, improved grazing management, restoration of degraded land, livestock manure management, better feeding management,

improved energy and feed efficiency, selection of more productive animal breeds, and transhumance practices.

Promoting development of and improved access to technologies and sharing knowledge of sustainable and climate friendly farming practices is vital. Within Ethiopia, research is needed at regional, zonal, district and community levels, to inform the development of adaptive strategies. To increase the resilience of Ethiopian farmers and herders, there is need for a sharper focus on development of improved crop varieties and animal breeds, and more sustainable and integrated management of crops, animals and natural resources, while providing other vital services for people and the environment (Alemayehu et al. 2007, IFAD 2009).

Adaptation and mitigation strategies should consider the different roles of men and women, and how they will be affected by climate change. Climate change clearly offers an opportunity to rethink gender inequality, and to involve both women and men in finding innovative solutions to common environmental challenges. The vast experience and knowledge of local people and indigenous institutions in adapting to climate variability is important for developing effective adaptation and mitigation strategies (Thornton et al. 2008; IFAD 2009).

11.5 Conclusions

There is enormous potential for livestock as a pathway out of poverty in Ethiopia. Climate change is an additional factor affecting livestock productivity and the livelihoods of those that depend on livestock. Majority of livestock keepers in Ethiopia are poor, therefore, the impact of climate change on livestock production is a serious concern. While global evidence shows that climate change impacts livestock directly through its effects on the rate of gain, feed use, milk production, and fertility, empirical evidence on the direct and indirect effects of climate change and variability on livestock in Ethiopia is limited. Very little is also known about the impact of non-climate stressors and their interaction with climate change. There is a strong need to support community-based adaptation programs with poor and vulnerable communities in rural and urban areas. Despite the important role of livestock in helping households deal with climate variability, a considerable gap exists in our knowledge of how climate change and increasing climate variability will affect livestock systems and livelihoods of people who depend on them. There is need for detailed assessments of the local impacts to help identify appropriate options that can help livestock keepers adapt to climate change.

Pastoralists managing significant proportions of national livestock herds are particularly vulnerable to climate change. Existing land tenure arrangements and services will come under increased pressure, exacerbating relations between communities and fuelling conflict.

Therefore, policies to enable herd mobility, while securing rights to critical resources (dry season pastures and water) are needed. Herd mobility should also include management of the various grazing areas to facilitate herd movement. Mobile pastoralists are amongst those most at risk to climate change, yet with the greatest potential to adapt to climate change, and may also offer one of the greatest hopes for mitigating climate change (Davies and Nori 2008).

Robust conflict management institutions, effective drought mitigation systems, including early warning, insurance and safety nets to protect livelihood assets are equally vital.

References

- Alemayehu N, Gebru G, Drucker GA. 2003. Reasons for the loss of animal genetic resources (AnGR) and the importance of IK in AnGR Management. In: Proceedings of the 11th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 28-30, 2003. pp 37-46.
- Alemayehu N, Tibbo M, Masafu MM, Tegegne A, Ebro A. 2007. Environment-Livestock Interaction and Technology Options for Adaptation in Ethiopia. Annual Conference and Workshop on “Science, Technology and Climate Change Adaptation in Africa”, Organized by the African Technology Policy Studies Network (ATPS), Nov 19-23, 2007 Johannesburg, South Africa.
- Assefa G, Gebeyehu A, Feyissa F, Tekletsadik T. 2002. On-farm performance of forage crops and assessment of natural pasture productivity in west Shewa zone. Proceedings of a workshop on client oriented research (Oct 16-18, 2001), Holetta Research Center, Ethiopia.
- Behnke R. 2010. The contribution of livestock to the economies of IGAD member states: Study findings, application of the methodology in Ethiopia and recommendations for further work. IGAD Livestock Policy initiative Working Paper No. 02-10.
- Berhanu K. 2006. Methane production and energy partitioning in *Bos indicus* cattle (Boran breed) fed on selected tropical feeds in Ethiopia. M.Sc. Thesis, School of Graduate Studies, Haramaya University.
- Brandjes PJ, de Wit J, van der Meer HG, Van Keulen H. 1996. Environmental impact of animal manure management. Working document, Livestock and the Environment: Finding a Balance. Rome: FAO/World Bank/USAID.
- Clark H, Pinares-Patino CS, Deklein C. 2005. Methane and nitrous oxide emission from grazed grasslands. In: McGilloway DA, ed. *Grasslands: A global perspective*. Wageningen.
- Clay J. 2004. World agriculture and environment. Washington DC: Island Press. 568 pp.
- Cunningham EP. 1995. Global impact domain: Animal genetic resources. Working document, Livestock and the Environment: Finding a Balance. Rome: FAO/World Bank/USAID.
- Davies J, Nori M. 2008. Managing and mitigating climate change through pastoralism. *Policy Matters* 16:127-141. (Available from http://cmsdata.iucn.org/downloads/pm16_section_3.pdf)
- Desta S, Coppock DL. 2002. Cattle population dynamics in southern Ethiopian rangelands. Research Brief 01-02-PARIMA. Global Livestock Collaborative Research Support Program (GL-CRSP), University of California Davis, USA.

- Desta S, Gebru G. 2003. Pastoral risk management to improve food security: Research and outreach experiences of GL-CRSP pastoral risk management project in southern Ethiopia. Paper prepared for the workshop on “Towards sustainable Food Security in Ethiopia: Integrating the Agri-food chain” held at Ghion Hotel, Addis Ababa, Ethiopia, 15-16 May 2003.
- Desta S. 1999. Diversification of livestock assets for risk management in the Borana pastoral system of southern Ethiopia. PhD Dissertation. Dept. of Rangeland Resources, Utah State University, Logan. 189 pp.
- Dourmad, J, Rigolot C, van der Werf H. 2008. Emission of greenhouse gas: Developing management and animal farming systems to assist mitigation. Livestock and Global Change conference proceeding. May 2008, Tunisia.
- Elasha BO, Elhassan NG, Ahmed H, Zakiieldin S. 2005. Sustainable livelihood approach for assessing community resilience to climate changes: Case studies from Sudan. AIACC working papers. 26 pages.
- Elias E. (2009). Threats of climate change on pastoral production under restricted herd mobility: A case study in Borana. SOS Sahel, Ethiopia.
- FAO. 2005. *Global forest resources assessment: Progress towards sustainable forest management*. Rome: Food and Agriculture Organisation.
- FAO. 2007. Adaptation to climate change in agriculture, forestry, and fisheries: perspective, framework and priorities. Rome: Food and Agriculture Organisation.
- FAO. 2008. Climate change adaptation and mitigation in food and agriculture sector. Technical background document from the expert consultation held in Rome 5-7 March 2008.
- FAO. 2009. Review of evidence on drylands pastoral systems and climate change: Implications and opportunities for mitigation and adaptation. Land and water discussion paper 8. Rome: Food and Agriculture Organisation.
- FAO. 2010. *Livestock and food security*. Produced by Natural Resource Management and Environment Department. Rome: Food and Agriculture Organisation.
- FEWS NET. 2005. Recent drought tendencies in Ethiopia and equatorial subtropical eastern Africa. (Available from http://pdf.usaid.gov/pdf_docs/PNADH997.pdf) (Accessed on 20 August 2013)
- FEWS NET. 2009. Recent rainfall and food aid tendencies in Ethiopia. (Available from <http://www.fews.net/pages/country.aspx?gb=et&l=en>)
- Fischer G, Shah M, Velthuisen H. 2002. *Climate change and agricultural vulnerability*. Laxenburg, Austria: International Institute for Applied Systems Analysis.

- Gebru G, Desta S. 2010. Seeking survival: The case of pastoral drop outs in Borana Plateau of southern Ethiopia. Presentation at the International Conference on Future of Pastoralism, 21-23 March 2010, ILRI, Addis Ababa, Ethiopia.
- Gebru G. 2008. Experiences on Prosopis management: Case of Afar Region. A study report submitted to FARM-Africa.
- Geleti D, Gizachew L, Hirpha A. 2001. Grain and forage yield responses of maize genotypes intercropped with lablab purpureus under Bako condition, Western Ethiopia. In: *Livestock in Food Security –Roles and Contributions*. Proceedings of the 9th annual conference of the Ethiopian Society of Animal Production (ESAP) held August 30-31, 2001. Addis Ababa, Ethiopia. p. 247-258.
- Georgis K. 2010. *Agricultural based livelihood systems in drylands in the context of climate change: Inventory of adaptation practices and technologies of Ethiopia*. Environment and Natural Resources Management Working Paper 38. Food and Agriculture Organization (FAO).
- Gerlanc NM, Kaufman GA. 2003. Use of bison wallows by anurans on Konza Prairie. *American Midland Naturalist* 150:158–168.
- Goodland R, Anhang J. 2009. Livestock and climate change: What if the key actors in climate change are... cows, pigs and chickens? World Watch, www.worldwatch.org.
- Grace J, San Jose J, Meir P, Miranda HS, Montes RA. 2006. Productivity and carbon fluxes of tropical savannas. *Journal of Biogeography* 33:387–400.
- Halderman M. 2004. *The political economy of pro-poor livestock policy-making in Ethiopia*. Pro-Poor Livestock Policy Initiative, Working Paper No. 19. Rome: Food and Agriculture Organization.
- Hoffmann I. 2008. Livestock genetic diversity and climate change adaptation. Livestock and Global Change conference proceeding. May 2008, Tunisia.
- Holechek JL, Pieper RD, Herbel CH. 2004. *Range management: Principles and practices*. Upper Saddle River, NJ; Pearson Education, Inc.
- Hurrissa B, Eshetu J. 2003. Challenges and opportunities of livestock marketing in Ethiopia. In: Jobre Y, Gebru G, eds. *Challenges and Opportunities of Livestock Marketing in Ethiopia: Proceedings of the 10th annual conference of the Ethiopian Society of Animal Production (ESAP)* Addis Ababa, Ethiopia, August 21-23, 2003. pp 1-14.
- IFAD. 2009. Livestock and climate change. Livestock Thematic Papers. (Available from <http://www.ifad.org/lrkm/events/cops/papers/climate.pdf>)
- IPCC. 2001. Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA: Cambridge University Press.

- IPCC. 2007. Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA: Cambridge University Press.
- IPMS. 2004. PRA (Participatory Research Appraisal) Diagnosis Survey of Ad Liben Woreda, Improving Productivity Market Success (IPMS). Addis Ababa, Ethiopia: ILRI.
- Kumsa T, Madsen JO, Tegegne A. 2004. Manure production, handling and use around Holetta Agricultural Research Center. The role of agricultural universities/colleges in transforming animal agriculture in education, research and development in Ethiopia: Challenges and opportunities. Proceedings of the 13th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 25-27, 2004. pp 3-12.
- Lekasi JK, Tanner JC, Kimani SK, Harris PJC. 1998. Manure management in the Kenyan highlands: Practices and potential. High Potential Production Systems Program of Renewable Natural Resources Knowledge Strategy Department for International Development Report. Kenilworth, UK: Emmerson Press.
- McSweeney C, New M, Lizcano G. 2007. Climate change country profile: Ethiopia. United Nations Development Program (UNDP)
- McSweeney C, New M, Lizcano G. 2008. Climate change country profile: Ethiopia. United Nations Development Program (UNDP). (Available from <http://country-profiles.geog.ox.ac.uk>)
- Mekasha Y, Tegegne A, Yami A, Umunna NN. 1999. Nutritional management of dairy herds in urban and peri-urban dairy production systems. Proceedings of the International Conference on the Nutrition of Herbivores, April 1999, Texas, USA.
- Mekasha Y, Tegegne A, Yami A, Umunna NN. 2002. Evaluation of the general farm characterization and dairy herd structure in urban and peri-urban dairy production systems in the Addis Ababa milk shed. Proceedings of the 10th Annual Conference of the Ethiopian Society of Animal Production (ESAP), August 2002, Addis Ababa, Ethiopia, pp. 137-144.
- Milchunas D, Lauenroth W. 1989. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs* 63: 328-366.
- MoARD. 2000. Second five year national livestock development plan of Federal Democratic Republic of Ethiopia (in Amharic). Addis Ababa, Ethiopia: Ministry of Agriculture and Rural Development.
- Mohamed-Saleem, MA. 1985. The establishment and management of fodder banks. In: von Kaufmann R, Chater S, Blench R, eds. Proceedings of the ILCA/NAPRI Symposium on

- Livestock Production In Nigerian Sub Humid Zone Kaduna, Nigeria, 29 October- 2 November, 1984. ILCA, Addis Ababa, Ethiopia. pp. 326-350.
- NMSA. 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). NMSA under the GEF supported Climate Change Enabling Activities Project of Ethiopia. Addis Ababa, Ethiopia: Federal Democratic Republic of Ethiopia Ministry of Water Resources and National Meteorological Services Agency (NMSA).
- [PADS] Pastoral Area Development Study. 2004. PADS general executive summary. Addis Ababa, Ethiopia: Ministry of Agriculture and Rural Development. 58pp.
- Pinares-Patiño CS, Baumont R, Martin C. 2003. Methane emissions by charolais cows grazing a monospecific pasture of timothy at four stages of maturity. *Canadian Journal of Animal Science* 83:769-777.
- [SC-UK] Save the Children–United Kingdom. 2009. Climate related vulnerability and adaptive capacity in Ethiopian Borana and Shinile communities. Final Report Assessment.
- Senbeta A. 2009. Climate change, impact on livelihood, vulnerability and coping mechanisms: A case study of West-Arsi Zone, Ethiopia. M.Sc thesis, Lund University, Sweden.
- Sere C, Ayantunde A, Duncan A, Freeman A, Herrero M, Tarawalli S, Wright I. 2008. Livestock production and poverty alleviation: Challenges and opportunities in arid and semi-arid tropical rangeland based systems. In: the proceedings of multi-functional grasslands in a changing world. XXI International Grassland Congress and VII International Rangeland Congress, China.
- Shibru M. 2001. Pastoralism and cattle marketing: A case study of the Borana of Southern Ethiopia. Master's Thesis. Dept. of Natural Resources, Egerton University, Njoro, Kenya. 115 pp.
- Sidahmed A. 2008. Livestock and climate change: Coping and risk management strategies for a sustainable future. In Livestock and Global Climate Change conference proceeding, May 2008, Tunisia.
- Steinfeld H, Wassenaar T, Castel V, Rosales M, de Haan C. 2006. Livestock's long shadow: environmental issues and options. Rome: Food and Agriculture Organization.
- Tegegne A, Gebrewold A. 1997. Prospects for peri-urban dairy development in Ethiopia. Proceedings of the 5th National Conference of the Ethiopian Society of Animal Production (ESAP), May 1997, Addis Ababa, Ethiopia. pp 28-39.
- Tessema T, Ulrichs C, Buettner C. 2009. Invasive alien plant species in Ethiopia: Impact, challenges and responses. (Available from <http://www.uni-goettingen.de/de/document/download/15aa8ee8edfc28378dbd674032ceeb96.pdf/INVASI>)

VE%20ALIEN%20PLANT%20SPECIES%20IN%20ETHIOPIA%20IMPACTS,%20CHALLENGES%20AND%20RESPONSES.pdf)

- Thornton PK. 2010. Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B* 365: 2853– 2867.
- Thornton P, Herrero M, Freeman A, Mwai O, Rege E, Jones P, McDermott J. 2008. Vulnerability, climate change and livestock – Research opportunities and challenges for poverty alleviation. ILRI, Kenya.
- [UN] United Nations. 2009. *World population prospects: the 2008 revision*. New York, NY: Department of Economic and Social Affairs, Population Division, United Nations.
- White R, Murray S, Rohweder M. 2000. *Pilot analysis of global ecosystems: Grassland ecosystems*. Washington, DC: World Resources Institute. 112 pp.
- World Bank. 2007. Climate change adaptation in Africa: a microeconomic analysis of livestock choice. World Bank Policy Research Working Paper No. 4277.
- Wu L, Topp CFE. 2008. The impact of climate change on grassland: A modeling approach. In: *The proceedings of multi-functional grasslands in a changing world*. XXI International Grassland Congress and VII International Rangeland Congress, China.

12. Climate change and food security: Survey of policies, programmes and strategies

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Abstract

Ethiopia is among the most vulnerable countries in the world. Recurrent droughts have led to serious food insecurity problems in the country. Agriculture, which is the mainstay of Ethiopia's economy, is vulnerable to frequent climate extremes. The IPCC regional review on the impacts of climate change identified agriculture, energy resources and health as the three most vulnerable sectors in Ethiopia. Food security will suffer due to rainfed agriculture which is affected by the amount and temporal distribution of rainfall. The government of Ethiopia has introduced different policies and strategies for drought-prone and food insecure areas. The formulation of the National Food Security Strategy in 1996 was mainly drawn from the smallholder-led agricultural development strategy. Since then, food security has been a central issue in different policies and programmes. Ethiopia, being dependent on rainfed agriculture, needs to adapt to climate change. While agriculture is the most vulnerable sector to climate change, it is also the second largest sector contributing to greenhouse gas emissions which requires mitigating actions. The relationship between climate change and food security has to be analysed from the context of agriculture and its interaction with the environment. This interaction is two-fold. First, the vulnerability of agriculture to fluctuations in environmental conditions is the main concern as this will affect productivity of the sector and in turn affects food security. Second, the contribution of the agricultural sector to climate change and the adaptation and mitigation efforts of countries justify the focus on agriculture.

Keywords

Policies; agriculture; food security; adaptation; mitigation.

12.1 Introduction

The Universal Declaration of Human Rights (UDHR) and a number of international instruments have recognized the right to food. The 1948 declaration provides that “everyone has the right to a standard of living adequate for the health and well-being of himself and his family including food”. The right to adequate food and the right of every person to be free from hunger are the notion of different international instruments ratified by Ethiopia. Furthermore, declarations like the United Nations Millennium Declaration endorsed by 189 member states in 2000 affirm nations’ commitment to eradicate hunger and poverty.

The right to food is not only limited to the availability of food in sufficient qualities, but also to the right of physical and economic access at all times to adequate food or to the means for its procurement. Food security refers to the overall availability of food—domestic production and amount of imported food (commercially or in the form of food aid).

Although food security has different contextual definitions, it has been argued that the definitions should at least have four main dimensions: food availability, access, utilization and stability. These components were clarified by the definition adopted by the World Food Summit (FAO 1996) that reads, “food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. For any country, food security can be achieved through either domestic production or food imports from other countries. In Ethiopia, agriculture is important to national food security because it is the main source of food.

In addition, agriculture is the backbone of the country’s economy, employing more than 84% of the population and contributing approximately 50% of Ethiopia’s GDP. It is also the major source of revenue accounting for more than 90% of the country’s exports (MoFED 2006). Agriculture in Ethiopia is mostly characterised by rainfed subsistence farming. Ethiopia has suffered from severe recurrent droughts and has been facing food insecurity since the 1970s. More than half of all households in the country have experienced at least one major drought shock in the period between 1999 and 2004.

Out of the total estimated land area of the country of 113 million hectares, about 73.6 million hectares (66%) is potentially suitable for agriculture. However, studies show that not more

than 15% of the land is under cultivation and the country is prone to drought that often leads to famine and deaths. The UNDP Climate Change and Human Development Report of 2006 indicate that the eastern and northern parts of the country are the most vulnerable and are the most food insecure.

Ethiopia has a long history of frequent famine and droughts. According to UNDP (2006), Ethiopia has been food insecure since the 15th century. Over 200,000 people died in the drought of 1973–1974. In 1974, about 1.5 million people (5% of the population) required food aid and the number grew to 7 million (17.4%) during the 1990s according to an FAO national report on Ethiopia. This report also indicates that about 14.5 million (22% of the total population) were food insecure in 2003. The number of people affected by drought and famine and people dependent on food aid has been increasing ever since. For many decades, therefore, there has never been a year in which the Ethiopian people were food secure.

Agriculture is one of the most vulnerable sectors to climate change. Climate change induced impacts on agriculture will make the communities poorer. In order to cope with these impacts there is need for measures to facilitate adaptation and mitigation. This paper examines the different policies, strategies and programmes that have been proposed by the government of Ethiopia to tackle problems of food security and discusses the importance, gaps, outstanding issues and constraints to implementing these programmes.

12.1.1 Review of national policies, strategies and programmes on agriculture and food security

Several attempts have been made by the former imperial, socialist and the current government of Ethiopia to tackle food insecurity. Different policies, strategies and programmes have been adopted by the government to tackle the problem of food insecurity in line with the country's international and constitutional obligations. The policies and strategies that have been put in place by the government include the Agricultural Development Led Industrialization (ADLI), the Sustainable Development and Poverty Reduction Program (SDPRP), Plan for Accelerated and Sustained Development to End Poverty (PASDEP), and the Growth and Transformation Plan (GTP) in addition to other specific policy tools within these documents.

12.1.2 Agricultural Development Led Industrialization

The government of Ethiopia has taken several measures to address food insecurity and drought. With the political stability and micro and macro reforms, different strategies and programmes have been designed to address food insecurity. The different strategies, policies and programmes for the development of the agricultural sector and food security are guided by the 1993 Agricultural Development Led Industrialization strategy (ADLI). ADLI aims to “bring about a structural transformation in the productivity of the agricultural sector.”

ADLI is the only framework that noted the development of agriculture was as important as industrialisation in the country’s attempt to reduce poverty. The strategy puts the agricultural sector to be the starting point of the structural transformation of the economy and focuses on creating different conditions for the country to be food sufficient. These conditions include improving smallholder agriculture, enhancing market-oriented agricultural raw materials and extensive use of the country’s natural resources and workforce. However, ADLI has been under criticism. Ethiopia’s agriculture is heavily dependent on rainfall, and critics argue it could not even feed the growing food demand, let alone production of raw materials for the industrial sector. Furthermore, for a country where the amount and distribution of rainfall is unpredictable and where land is highly vulnerable to degradation, the country has remained food insufficient.

12.1.3 Plan for Accelerated and Sustained Development to End Poverty

The Plan for Accelerated and Sustained Development to End Poverty (PASDEP) is a document in which the Ethiopian government aims to reduce poverty over the period between 2005/06 and 2009/10. PASDEP is the second phase of the Poverty Reduction Strategy Program (PRSP) process, the first phase being the Sustainable Development and Poverty Reduction Program (SDPRP) of 2002/03–2004/05 (FDRE 2002).

The ADLI Strategy was among the pillars of SDPRP. During the SDPRP period, the government resource allocation and implementation focused on investments in development and pro-poor sectors such as agriculture, food security, education and human health. The strategy aimed at accelerating and expanding industrial development and increasing the overall economic growth. The major achievements of SDPRP included channelling of grants to the regions for enhancing agricultural production in food insecure areas and launching of

the National Food Security Program (FSP). However, the programme has been criticized for low agricultural productivity aggravated by land degradation and high dependence on rainfed subsistence agriculture.

The PASDEP also placed agriculture at the centre of its growth strategy in which the private sector was expected to play the leading role. PASDEP took forward a number of similar measures emphasized by its predecessor—the SDPRP. PASDEP priorities included food security, rural development, human development, and capacity building. The programme also introduced new emphasis and mechanisms for commercialisation of agriculture as a strategy for stimulating broad-based economic growth. PASDEP renewed the Government of Ethiopia’s commitment to the FSP, which was initiated by the ‘New Coalition for Food Security’³ after the food crisis of 2002 (MoFED 2006). However, it has also been condemned for failing to build on the experience of the SDPRP and for being a desktop policy document. Furthermore, the distribution and late onset of rainfall affected agricultural productivity. Due to high inflation rates, food prices rose significantly, which contributed to food insecurity.

12.1.4 Rural development policies, strategies and instruments

The Rural Development Policy (RDP) of Ethiopia states that 85% of the country’s economic policy is focused on the rural areas where the larger share of the population lives (FDRE 2002). The policy issued in 2002 discussed some new strategies in addition to the previous programmes discussed. Some of its strategies include proper use and utilisation of manpower and arable land, specific rural development packages for different ecological areas, infrastructure development, capacity building programmes and promotion of market led agricultural development.

The RDP introduced a programme to review the rural financing mechanisms, improving macro-finance and rural banking systems. The aim was that farmers would have the financial access to develop their farming systems and become food sufficient. Furthermore, encouraging private sector investment in agriculture was discussed as an important tool.

³ New Coalition for Food Security was established after the famine in 2002/2003. The key feature of the coalition was the establishment of safety nets aimed at protecting household assets, in addition to strengthening the agricultural sector.

The RDP focused on three main objectives: having agricultural and rural-led economic development, making the country food sufficient by abolishing dependence on foreign aid, and a free market economy based on agriculture. The policy is based on the anticipation of the government that the rural sector could generate real GDP. The RDP was a foundation of different strategies and programmes such as the food security and resettlement programmes.

12.1.5 Food Security Strategy (FSS)

Food insecurity can either be chronic or acute. The 2002 Food Security Strategy (FSS) defines chronic food insecurity as commonly perceived food deficiency as a result of overwhelming poverty and lack of assets (FDRE 2002). On the other hand, food insecurity caused by a transitory phenomenon caused by natural (drought) or human-made (social/market) shocks is defined as acute food insecurity. The FSS clearly states that chronic and transitory food insecurity is widespread and severe in Ethiopia. Millions of households in rural areas of Ethiopia suffer from chronic food insecurity and receive food aid regularly. Food security reforms were initiated in 2002 when the FSS was issued under the PASDEP discussed above.

The main objective of the FSS was to ensure food security at household level. In addition, new ideas were implemented to address the needs of food insecure households in more sustainable ways. In order to attain food security, the strategy put forward four major components: voluntary resettlement programme, direct food production, income diversification and the productive safety net programme. These are briefly discussed in the following sections.

12.1.6 Voluntary Resettlement Programme

The Voluntary Resettlement Programme (VRP) programme was developed in response to the problems of highland degradation, high population growth rate and small farm size in moisture deficit areas. As a component of the FSS, the resettlement programme promoted access to improved land systems. The VRP was originally introduced within the Rural Development Policy and aimed at voluntarily resettling chronically food insecure farmers and pastoralists to suitable underutilized lands. The programme also aimed at contributing to the country's economic growth by utilizing under-cultivated lands and improving the welfare of the resettled farmers.

In order to achieve this goal, the Ethiopian government provided minimum infrastructure including schools, health facilities, roads and water systems. Furthermore, each settler household was supposed to be allocated a package of assistance that included access rights of up to 2 hectares of fertile land, seed, oxen, hand tools, utensils, and food rations for the first 8 months. However, the VRP has been controversial due to fears as to what humanitarian consequence might prevail if the programme fails. Donors have also been very reluctant in supporting the programme fearing its consequences.

12.1.7 Productive Safety Net Programme (PSNP)

Due to the demand for emergency food assistance and an increase in the number of people in need of emergency food assistance, the government of Ethiopia designed a Productive Safety Net Programme (PSNP) in 2005 to address chronic food insecurity. . For example, the number of people in need of emergency food assistance increased from 2.1 million in 1996 to 13.2 million in 2003. However, it decreased to 7.1 million in 2004 (World Bank 2004).

From 2005, a revised PSNP was initiated by the government and a consortium of donors. The programme has reached more than 8 million food insecure Ethiopians each year and operated on a budget of nearly USD 500 million per year. At the beginning, the beneficiaries of the PSNP were identified from different food insecure households in eight different regions. The programme then expanded into Afar region in 2006 and Somali region in 2007.

The PSNP is the second largest social protection scheme⁴ in Africa. The programme has two key objectives: precluding asset depletion as most people sell off their essential assets to meet their food needs, and secondly engaging in public works⁵ for generating assets. However, the programme also has a provision for direct support for households that are labour constrained due to different reasons and if there is no other source of support. The ultimate goal of the programme is to incorporate chronically food insecure households to participate in the different food security programmes (access to credit, agricultural extension, technology transfer, cash crop seeds) and help raise their families out of poverty.

4 Social protection is a set of public actions that provide direct support to people to help them address risk, vulnerability, exclusion and poverty including social insurance, minimum standards and social transfer (DFID 2007).

5 Public works wage rate is 6 Birr (\$0.70) or 3 kg of grain per day. Direct support benefits are 30 Birr (\$3.50) or 15 kg of grain per person per month. Transfers are made to participants for six months of the year. (DFID)

The PSNP works through government financial and food distribution systems. The Ministry of Agriculture oversees the process and coordinates regional food security bureaus and desks. The programme faced some challenges in the early phase and has been criticized as arguably creating dependence as individuals registered in the programme showed no interest in growing out of poverty due to the easy cash and food transfers.

12.1.8 Growth and Transformation Plan

The Growth and Transformation Plan (GTP) of the Ethiopian government was adopted in November 2010 (MoFED 2010). The GTP is a comprehensive document that evaluates the performance of the economy over the previous five-year-plan period (2006–2010). It is forward looking and has highly ambitious sectoral targets for the following years (2011–2015). The focus of GTP ranges from national socio-economic issues and macro-economic goals, and to specific details of assets to be acquired by individuals by the end of 2015.

Addressing food insecurity problems is one of the most important components of the plan. GTP is based on the experiences from the previous food security programmes and will continue to assist moisture deficit and food insecure areas. The GTP will continue to promote inclusive and progressive programmes like the household asset building, safety net, resettlement programmes and off-farm income generating activities. The PSNP will be implemented jointly with household asset building programmes to reduce problems of natural degradation and to enable communities to build community assets. GTP plans and promotes the provision of training, technology supply, credit and extension for PSNP beneficiaries in its bid to realize food security.

Furthermore, capacities building on early warning for disaster prevention and response systems as well as staff are among key tasks of the plan. The aim is to take timely measures in response to agricultural and food emergencies and to develop better preparedness for food security disasters. The GTP has set projections and selected targets for different sectors. The agricultural sector will remain the mainstay of the country by contributing a projected real GDP from 35.5% base to 41% in best-case scenarios by the end of the plan year. In order to attain this, agricultural production is targeted to grow by between 8.1% and 14% on average during the second five year plan.

Among the selected GTP focus areas for the government's ambitious targets is to reduce the number of households participating in the PSNP from 7.8 million from the baseline year of 2009/10 to 1.3 million in year 2014/15. Critics, however, argue that agriculture not be the main engine for economic development, especially when the rural areas do not have sufficient conditions for using improved technology and commercialization. Rather than stating the country will remain under single digit inflation by demonstrating high economic growth, it has strongly been criticized for not providing how the government intends to achieve price stability in the coming five years. Considering the high inflation rates experienced during PASDEP and increases in food price worldwide, the question of food security is at risk.

12.1.9 Other institutional and legal frameworks

The Disaster Prevention and Preparedness Commission (DPPC) was established in 1995 under proclamation number 10/1995. The DPPC succeeded its predecessor, the Relief and Rehabilitation Commission, which was established in June 1974. The DPPC has three main responsibilities. The first responsibility is prevention of disasters by tackling their root causes. Second, DPPC ensures preparedness is manifested in building the capacity needed to reduce the negative consequences and impact of disasters. Finally, the commission is responsible for responding to disasters and providing the necessary emergency assistance to the victims.

According to the National Policy on Disaster Prevention and Management adopted in 1993, the government intends to deal with the root cause of the problems and prevent the occurrence of disasters. The commission was established because of famines, which continues to be at the centre of what the commission does. One of the areas the commission focuses on is reduction of vulnerability to famine and food shortages. The commission uses relief assistance and community-based projects as tools for dealing with famine disasters. The commission tries to link its food security initiatives with contributing to the development of the country through environmental protection, development of infrastructure and building community assets with drought free content.

As part of the mandate of the commission, an Early Warning System (EWS) was put in place. The EWS was originally established in 1976 and aims to monitor and warn of the threat of disasters ahead of time, and to trigger timely, appropriate and preventive measures. The DPPC coordinates the national EWS system, which was decentralized to regional levels in

1993. The system monitors factors that have implication on food security and compiles monthly reports.

The Emergency Food Security Reserve (EFSR) established in 1992 by Proclamation 67/2000 is a reserve that provides readily available food in time of emergencies on loan basis. The reserve has a physical storage capacity of more than 300 metric tons, as part of the preparedness mandate of the DPPC. In addition to the physical reserve, the DPPC is also responsible for the National Disaster Prevention and Preparedness Fund (NDPPF) established under the Proclamation 212/2000, which is used to finance emergency supplies of food to the needy. The government and donors contribute to the fund. Although the DPPC has responded to drought in the past and also focuses mainly on drought related disasters, it also keeps a National Non-Food Contingency Stock. The need for this stock relates to disasters such as floods and epidemics that have occurred in recent times.

Currently, the DDPC is developing a National Policy and Strategy on Disaster Risk Management. This draft policy framework has an objective to reduce risks and the impacts of disasters through the establishment of a comprehensive and integrated disaster risk management system within the context of sustainable development (DPPC 2011). This policy has pre-disaster, disaster and post-disaster phases for preventing and minimizing risk.

12.2 Climate change impacts and vulnerabilities on agriculture and food security

12.2.1 Impacts on agriculture and food security

Agriculture has been and will remain to be the mainstay of the country's economy. Agriculture plays a vital role in economic development. It has been the source of food and important for food security through domestic production and foreign exchange for accessing additional food from the international markets. Ethiopia has a long history of drought and famine coupled with high poverty levels, rapid population growth and high dependence on rainfed agriculture. Food insecurity and drought are not new to Ethiopia unlike the other impacts of climate change.

In the past, reported cases of drought and famine were about one in nine years and on average one in seven years. However, reports after 1950 indicate that 18 droughts/famines were recorded in 38 years, making the occurrence of drought to be once in about every two years.

Climate change has direct and indirect impacts on agriculture including higher temperatures, reduced or increased rainfall resulting from change in rainfall patterns and declines in crop yields and loss of productivity.⁶ Ethiopia's agricultural performance has been impacted by climate change. The country has suffered from unprecedented drought and food insecurity.

Ethiopia has already suffered from extremes of climate change manifested in the form of frequent droughts. Since the 1980s, there have been five major droughts and on average one drought per year was recorded since 2003. In addition, from the year 2000 up to 2005, 3.8 million to 12.2 million people were estimated to be in need of food assistance, while the number on average remained to be around 8 million until 2010/11. Among these people were 2 million children who were malnourished due to drought-induced food shortage (UNDP 2007/08). Studies indicate that crop yields have declined and will continue to decline causing food insecurity (Oxfam International 2010). Climate change-induced losses in yield that lead to cereal price increases in international markets also lead to high cereal prices nationally. Ethiopia has recorded a 30% inflation rate on cereal prices, which is expected to continue for the coming months (GIEWS-FAO 2011).

12.2.2 Vulnerabilities⁷ of agriculture and food security

Africa is already under pressure from climate stresses and is highly vulnerable. IPCC reports also indicate that the continent is one of the regions that will be hit hardest by the impacts of climate change (IPCC 2007). The vulnerability of sectors to climate change depends on major factors such as their exposure to hazardous impacts, dependency on climate sensitive resources and geographical and topographical situation. Furthermore, it depends on adaptive capacity of the sector (IPCC 2007). Ethiopia is among the world's twelve countries on the climate change hit list (World Bank 2009). The country is highly dependent on rainfed agriculture. In addition, its low adaptive capacity in combination with its geographical

⁶ The change of CO₂ in the atmosphere influences the growth of crops and weeds by changing the process of photosynthesis and it increases the length of growing period of some crops. Photosynthesis uses solar energy to combine water and carbon dioxide to produce carbohydrates and with oxygen as a waste product. Different crops are positioned to benefit from the effects of carbon fertilisation (rice, soybeans and grains). Nonetheless, climate induced effects still can decline 30% and 12% of cereal and production of rice, soybeans and others. Also, higher atmospheric concentrations of CO₂ reduce the stomatal/pore opening which cause water respiration.

⁷ IPCC defines vulnerability as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.'

location puts the country among the most vulnerable countries in Africa. The extreme poverty level in the country is also an exacerbating factor to the vulnerability ranking of the country.

The IPCC reports of 2001 and 2007 have identified three vulnerable sectors in Ethiopia: food security, energy resources and health. The UNFCCC climate change impacts and vulnerability impact assessment report stated that agriculture and food security will be the most vulnerable sectors to climate change. A recent study indicated that Afar and Somali are the most vulnerable regions of Ethiopia followed by Oromia and Tigray among the 11 regional states excluding Addis Ababa, Dire Dawa, Harari and Gembella. These vulnerabilities are attributed to higher frequencies of droughts and floods and low adaptive capacity and infrastructural development, respectively. However, the South Nations Nationalities and Peoples (SNNP) region has a lower vulnerability rate compared to the above. The region has relatively greater access to technology and markets, larger irrigation potential, and higher literacy rate (IFPRI 2008).

The impact of climate change on food insecurity and malnutrition could be very severe. The International Food Policy Research Institute (IFPRI) estimates that the risk of food insecurity will increase due to declines in production of 20% by 2025. In addition, 24 million undernourished children will be living in the sub-Saharan Africa region by 2050. In order to reduce the effects of climate change, countries should have designed their adaptation and mitigation measures accordingly.

12.3 Strategies for developing adaptation and mitigation actions: integration into national policies and action plans

Climate change induced impacts on agriculture have affected the poor and caused crop failures and food insecurity. The impacts of climate change are expected to undermine the ability of people and the ecosystem to cope with, and recover from extreme climate events and other natural hazards. Adaptation measures are needed urgently to reduce the adverse impacts of climate change, facilitated by concerted international action and strategic country planning. The IPCC promotes planned adaptation to cope with changes of the environment (IPCC 2007). Estimates indicate that the global costs of adaptation for the agricultural sector will reach around USD 14 billion per annum, of which developing countries will need more than USD 7 billion annually (UNFCCC 2007).

Effective adaptation strategies will entail adjusting to the changes in climatic conditions at national and international levels. The strategies may vary, and are usually very specific to the location and sector (IPCC 2007). These strategies should be able to secure human and ecological well-being in response to the change in climate conditions and variability. Furthermore, strong adaptation strategies should focus on building resilience and also support for the decision-making and capacity building processes that shape social learning, technology transfer, innovation and development. Ethiopia could use these different adaptation measures in the agricultural sector. Among these are new crop varieties that are tolerant/resistant to drought, salinity, insects/pests; and water supply and irrigation systems, application of new technologies; new land management techniques; and efficient water-use techniques. Furthermore, policy measures like tax incentives and subsidies, free market system and development of an early warning system could help build a climate resilient agricultural system (UNFCCC 2007, Kato et al. 2009).

Crop and livestock production emit CO₂, methane and nitrous oxide making the agricultural sector the second major source of greenhouse gases (GHG) emission followed by industries and wastes. The UNFCCC estimates that agricultural activities account for 15% of global GHG emissions and deforestation adds around 11% making the agricultural sector the second largest contributor of GHG emissions following the energy sector. The mitigation potential of the agricultural sector could also be significant (IPCC 2007). There are different opportunities for the agriculture system to decrease its GHG emissions. These include use of improved crop and land management and less intensive agricultural production (less use of chemicals, fertilisers, and pesticides). Also, emissions of CO₂ from changes in agricultural land use can be reduced by decreasing deforestation, which could reduce CO₂ and also be a carbon trading scheme in return for conservation of forest areas. A World Bank report (2010, p. 171) states that “a soil compliance carbon market holds great potential for helping to achieve the necessary balance between intensifying productivity, protecting natural resources, and simultaneously helping rural development in some of the world’s poorest communities.” The emerging market for trading carbon emission offers new possibilities for carbon filtration. However, the parties of UNFCCC should adopt different mechanisms for these trading schemes.

12.3.1 Climate change in national policies and action plan: adaptation and mitigation

In the past decades, the government of Ethiopia mainly focused on reducing poverty. However, the different national policies and sector strategies had directly and indirectly incorporated adaptation options to reduce vulnerability of the agricultural, water and health sectors to climate change (NMA 2007). The Ethiopian Constitution of 1994, Article 44, the pillar of Ethiopian response to climate change, and the Environmental Policy of 1997 raise issues of environmental rights and climate change. Furthermore, different policies such as the National Population Policy (1993), Water Resource Management Policy (1994), Agricultural and Rural Development Policy and Strategy (2002), and PASDEP (2005–2010) discuss informal adjustments to the different adverse changes in the country.

The GTP has one of the strong frameworks and timelines compared to the policies and strategies mentioned above in relation to incorporating climate change adaptation and mitigation actions. The GTP states that environmental conservation has vital contribution for sustainability of development and has set an objective to formulate policies, strategies, laws and standards. These legal frameworks can foster social and economic development to enhance human welfare and safety and sustainability of the environment.

The GTP aims to build a Climate Resilient Green Economy (CRGE) by 2025. The pillars of CRGE will be the National Adaptation Programme of Action (NAPA) (2007) and National Appropriate Mitigation of Action (NAMA) (2010). The plan has a clear vision and timeline for reducing GHG emissions in Ethiopia. The CRGE targets include long-term land use, higher yields and food security, and carbon sequestration and soil carbon restoration for adaptation and mitigation, respectively.

12.4 Conclusions

Ethiopia is one of the countries most affected by frequent food shortages and at times chronic famine. Recurrent droughts have caused chronic and seasonal food insecurity affecting about 22% of the population. There has never been a year that has passed without the country experiencing food insecurity problems. In addition, changes in the distribution and amount of rainfall have negatively affected rainfed agriculture. Projections show that climate change is likely to reduce yields of wheat, a staple crop, by 33% and cause loss of fertility.

The government of Ethiopia has put in place different policies, strategies and programmes to deal with food insecurity. The objectives of the strategies are to ensure food security at household level. The different instruments have identified important elements and measures that are crucial to address the food insecurity problems in Ethiopia. The programmes focus on increasing the production and productivity of the agricultural sector. Despite, the policies, strategies and programmes, the country still faces frequent problems of food security.

In addition, the government of Ethiopia also prepared and submitted its NAPA (in 2007 and NAMA to the UNFCCC Secretariat (in 2010). These national responses can be incorporated and the already existing frameworks updated to have sustainable and productive agriculture and higher crop yields through water harvesting technologies and enhanced environmental rehabilitation.

The key challenge, however, has been how to translate these policies and programmes into national, regional and local capacity. Even if the programmes have made contributions in creating and protecting household assets, the capacity of regional authorities to implement the policies and national response to climate change should be enhanced. The importance of communicating and involving communities could also be an effective approach for implementation. Furthermore, different mechanisms such as risk reduction, use of appropriate technologies and acquiring finance from carbon trading schemes should be explored.

References

- DPPC. 2011. National policy and strategy on disaster risk management. Addis Ababa, Ethiopia.
- [FAO] Food and Agricultural Organization. 1996. World food summit plan of action. p. 13–17.
- [FDRE] Federal Democratic Republic of Ethiopia. 2002. Rural development policies, strategies and instruments. Addis Ababa.
- [FDRE] Federal Democratic Republic of Ethiopia. 2002. Sustainable development and poverty reduction programme. Addis Ababa.
- [FDRE] Federal Democratic Republic of Ethiopia. 2002. Food security strategy. Addis Ababa.
- GIEWS and FAO. 2011. Global information and early warning system on food and agriculture. GIEWS Country Brief.
- IFPRI. 2008. An analysis of Ethiopia’s Productive Safety Net Program and its linkages. International Food Policy Research Institute.
- IPCC. 2001. Intergovernmental Panel on Climate Change Secretariat. Third Assessment Report. Geneva, Switzerland.
- IPCC. 2007. Intergovernmental Panel on Climate Change Secretariat. Fourth Assessment Report. Geneva, Switzerland.
- Kato E, Ringler C, Yesuf M, Bryan E. 2009. Soil and water conservation technologies: A buffer against production risk in the face of climate change? Insights from the Nile basin in Ethiopia. IFPRI Discussion paper 00871.
- [MoFED] Ministry of Finance and Economic Development. 2006. Ethiopia: Building on progress: A plan for accelerated and sustained development to end poverty (PASDEP) (2005/06–2009/10).
- [MoFED] Ethiopian Ministry of Finance and Economic Development. 2010. Growth and transformation plan.
- NMA. 2007. Climate change national adaptation program of action (NAPA) of Ethiopia. Addis Ababa, Ethiopia.
- Oxfam International. 2010. The rain doesn’t come anymore: Poverty, vulnerability, and climate variability in Ethiopia.
- UNDP. 2008. Human Development Report 2007/2008. Fighting Climate Change: Human solidarity in a divided world. New York: United Nations Development Programme.
- UNFCCC. 2007. Climate change: Impacts, vulnerabilities and adaptation in developing countries, assessment report.

UNFCCC. Nationally Appropriate Mitigation Actions for Ethiopia available at
http://unfccc.int/files/meetings/application/pdf/ethiopiaphaccord_app2.pdf.

World Bank. 2009. *Convenient solutions to an inconvenient truth: Ecosystem-based approaches to climate change*. Washington DC: World Bank.

World Bank. 2010. World Development Report 2010: Development and climate change.

13. Mainstreaming climate change in Ethiopia's agricultural and food security policies

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Abstract

Climate change poses significant threats to agriculture and food self-sufficiency in Ethiopia. Resilience to climate change is seriously compromised as a result of out-dated practices characterised by overdependence on natural resources, dependence on variable rainfall, poor performance in infrastructure development and inefficient allocation of scarce resources.

Currently, there is a great deal of national attention to address climate change in the agricultural sector. Bottom-up and top-down approaches have been taken up by the government as described in this paper. In the Ethiopian context, the concept of mainstreaming climate change issues into the agricultural sector spans two spectrums—mitigation (reduction of greenhouse gases) and adaptation (putting in place resilience measures to withstand possible climate change impacts). The paper qualitatively describes the understanding within the government context on “climate mainstreaming” and appropriate approaches.

Keywords

Mainstream; adaptation; mitigation; vulnerability; food security.

13.1 Changing climate projections and food security implications

Climate change is a global phenomenon with local implications. Climate change is caused by accumulation of greenhouse gases (GHG) in the lower part of the atmosphere. The stock of these gases has risen from 280 parts per million (ppm) of carbon dioxide equivalents before the industrial revolution to 430 ppm in recent years (Stern 2006). The increase in the concentration of the gases is the cause for the rise in temperature and disruption of rainfall patterns, causing disturbances in ecosystem functioning and extreme events. Temperature rise is marked to have reached its record high in 2010 (IETA 2011), and is still on the rise in the absence of a common binding goal for curbing GHG. This is likely to arrest the demand by the international community to keep global warming below the agreed upon 2°C and hamper ambitions to even further limit the rise to the scientifically desired threshold of 1.5°C (IPCC 2007). Developing countries in Africa are projected to feel the worst impacts because of these alterations, with the agricultural sector being the most vulnerable.

Projections show that the world population will reach around 9 billion by 2050, with most of the increase occurring in a few countries, including Ethiopia (UN 2009). Ethiopia's population is expected to reach 130 million with a density of 150 people per square kilometre by 2050 (UN 2009). This is expected to put enormous pressure on agricultural production to feed the growing population. More than 70% of the population in Africa as well as other regions such as the Caribbean and Pacific are highly dependent on agriculture. The sector is the main driving force of growth and food security in most developing countries (CTA 2008). Given the rising population, the challenge of meeting this demand is in itself daunting. In addition, climate change is complicating matters and hindering the struggle to attain food and nutritional security within these regions.

The agricultural system of developing countries like Ethiopia will be particularly vulnerable to climate change impacts (IPCC 2007). Agricultural losses will be severe for East Africa 'accompanied by changes in length of growing periods impacting mixed rainfed, arid, and semi-arid systems under certain climate projections' (IPCC 2007).

13.2 Climate change impact on agriculture in Ethiopia

13.2.1 Rising temperature and rainfall variability

During the second half of the last century, the average annual maximum temperature in Ethiopia rose by about 0.1° C every 10 years, while the national average annual rainfall was relatively stable (NMA 2007). However, the national trends mask differences across the different agricultural zones in Ethiopia, which in some cases contradict the national trends. In the northern half and southwestern parts of the country, the rainfall amounts has fallen since the 1970s, while an increasing trend is observed in the central highlands (NMA 2007). Future projections on rainfall patterns indicate a rising trend in the arid southeastern part of the country (IPCC 2007).

13.2.2 Loss of land productivity

The economy of Ethiopia largely depends on agriculture. Agriculture contributes to about half of the gross national product (GNP). More than 80% of the national exports come from agricultural products and the sector accounts for 85% of total employment in the country. Any changes in the sector because of climate change is, therefore, likely to destabilize the economy. A decline in economic growth will further complicate the situation as it will leave poor people highly vulnerable to climate change impacts (Mertz et al. 2009).

Agriculture is predominantly subsistence and largely depends on highly erratic rainfall. As a result, the sector is significantly vulnerable to climate change. Coupled with this, extreme climatic events such as droughts and floods are further deteriorating soil fertility and nourishment, worsening land productivity. Flooding disasters in various parts of the country and recurrent droughts have been reported. In 2006, a major flooding disaster resulted in loss of life and property in different parts of the country (FfE 2006). According to the rapid assessment made at the time by a local NGO (Forum for Environment), more than 600 people died and more than 10,000 people were rendered homeless in Dire Dawa alone. In Southern Omo and West Shewa regions, 22,000 people were displaced. In addition, the floods also led to loss of 2700 herds of cattle, while food crops stored in 760 silos were washed away. Similarly, pest infestation of arable land and encroachment of invasive alien species is becoming a regular phenomenon in the country. Coupled with this is an uncontrolled rise in population. This has necessitated changes in land use patterns, resettlement and expansion of

agricultural production into forested and wetland areas—again significantly compromising resilience of the sector to climate change and variability.

13.2.3 Declining food security and the need for resilience

Studies demonstrate a declining trend in food security in Ethiopia. In 2000 alone, 10.5 million people were affected by drought leaving 13 million people food insecure. Recent estimates (EPA 2011a) hold that:

“Chronic food insecurity affects 10% of the population and even in average rainfall years these households cannot meet their food needs and they rely partly on food assistance. Droughts can result in sharp reductions in agricultural output and related productive activities and employment, with multiplier effects on the monetary economy. Floods regularly cause crop and infrastructure damage and widespread suffering and hardship, with, for example, several tens of thousands of people being displaced and over ten thousand hectares of cropland inundated in Afar and Amhara regions in 2010”.

This justifies the urgent call for adaptation in the agricultural sector. Measures addressing vulnerability to the global change needs to be put in place. The alarming facts are indicators on the need to take coordinated actions now, and linking these actions to the overall national development plan.

13.3 Mainstreaming climate change into the agricultural sector

13.3.1 Definitions and approaches

The first strategy by the global community to tackle the problem of climate change was reducing GHG emissions. Emissions of CO₂, however, cannot be stopped right away given its complicated linkages with socio economic development and large dependence of large economies on fossil fuel. Accumulation of GHGs will continue over the coming decades regardless of mitigation efforts by nations (Aplet et al. 2010). Even if this was possible, the inertia created due to the already existing concentration would still result in further warming and hence impacts on the natural system (Mertz et al. 2009). Adaptation, therefore, should be a focus of actions particularly within developing nations where adaptation is important for survival.

The term ‘adaptation’ may mean many things. Adaptation to climate change is a process through which people reduce its adverse effects on health and well-being and take advantage of opportunities that the environment provides. IPCC (2007) defines adaptation as “adjustment in natural or human systems in response to actual or expected stimuli or their effects which moderates harm or exploits beneficial opportunities.” Saka (2008) summarizes two core components of adaptation measures with a given sector as i) measures that reduce vulnerability, and ii) measures that increase resilience through the utilization of available assets.

According to IPCC (2007), adaptive measures are categorized into three classes: i) anticipatory, ii) autonomous and iii) planned. From these three categories, planned adaptation is in line with mainstreaming climate change into government programmes. Planning denotes proactive intervention and hence it implies deliberate and considered actions resulting in a policy that brings about a desired outcome.

13.3.2 Mainstreaming approaches

Mainstreaming will help to entrench climate adaptation into agricultural policy processes. The IPCC (2007) determined with high confidence that smallholder and subsistence farmers and pastoralists are likely to suffer complex and localized impacts of climate change thus putting short term adaptation needs in avoiding a 10–15% reduction in yield as most significant. So far efforts in streamlining climate into development in Ethiopia are approached at two levels: strategic and project levels. This paper discusses both levels, with more focus on the strategic level. The steps taken so far to strategize national actions to assist vulnerable sectors and communities are also described.

13.3.3 Setting the vision for Ethiopia

Over the last few years, Ethiopia has recorded a marked economic growth in all economic sectors, with agriculture playing a leading role. The government is consistently affirming its commitment to sustain high economic growth to enable Ethiopia to become a middle income country by 2025. This is mainly reflected in the ambitious short to medium term national plan referred to as the Growth and Transformation Plan (GTP), the implementation of which runs through 2015 (MoFED 2011). At the same time, the country has realized the effects of climate

variability on agricultural production and that it poses a big threat to sustained growth of the sector (EPA 2011a).

The environmental ambition based on government statements⁸ and outlined within the Climate Resilient Green Economy (CRGE) mission statement is to enable and undertake a clean growth pathway that is carbon neutral. The idea is to offset the inevitable emission of GHGs resulting from economic development through a combination of mechanisms as outlined in the National Appropriate Mitigation Actions (NAMA) for Ethiopia.⁹ This marked the beginning of the work to develop the mission statement for CRGE as a precursor for designing a national strategy on climate change. As stated above, one of the sectors identified for its immediate adaptation needs as well as its potential for mitigation is agriculture.

13.3.4 Climate Resilient Green Economy

The two building blocks of the Climate Resilient Green Economy (CRGE) are climate resilience and green economy outlined under the Ethiopian Programme of Adaptation on Climate Change (EPACC) and the NAMA (EPA 2011c). The work programme for the development of the CRGE mission statement indicates that its goal is to create a nationally approved strategy on climate change. The mission statement encompasses both the adaptation and mitigation strategies to be undertaken in Ethiopia together with a mechanism of channelling financial resources for implementation of outlined actions. It also includes an approach to monitor, verify and report implementation successes. Agriculture, livestock productivity, soil nourishment and forestry are key components of this work in progress.

13.3.5 Mainstreaming agricultural adaptation within the EPACC

Mainstreaming agricultural adaptation has been through two approaches—top down and bottom up (EPA 2011b). This is based on the thinking that the government (at the top) should assume the triggering role, while the communities (at the bottom) that are experiencing the real threats will highlight their specific vulnerabilities and their perceived strategies and

⁸ Statement by Prime Minister Meles Zenawi at various fora (see for example <http://www.forestcarbonportal.com/news/ethiopia-reforest-15m-hectares>)

⁹ Nationally Appropriate Mitigation Actions (NAMAs) are results of the moral obligations imposed on developing nations through the 2009 Copenhagen Accord. The Accord is the political document that resulted from the 15th Conference of the Parties (COP15) of the United Nations Framework Convention on Climate Change (UNFCCC) that took place at the end of 2009 in Copenhagen, Denmark.

measures to deal with the threats. Results from both the top down and bottom up approaches will be synthesized into a single national document.

Top-down mainstreaming

Assuming a triggering role, the government of Ethiopia developed a draft programme on adaptation to climate change for review by agencies from various sectors in March 2010. The draft programme was reviewed by representatives from sectoral federal government agencies, regional governments, research organizations, institutions of higher education, religious institutions, national non-governmental organizations and the private sector. The review culminated in adoption of a way forward that was expected to run for a period of 6 months. As of July 2011, the final programme was near completion but not yet compiled as a final version. In addition, sectoral and regional plans that were crafted independently needed to be consolidated. It is therefore premature to discuss the contents.

However, information can be obtained from initial document that was presented by the Environmental Protection Agency (EPA), and the process for the preparation of regional documents. The draft presented by EPA summarizes possible climate change challenges in the future. It also points out possible measures of dealing with the impacts for each sector in question. From the 20 vulnerability spots addressed, most refer to possible risks in the agriculture sector. The agriculture section of the draft document is summarized in Table 13.1.

Table 13.1 Agriculture vulnerability and responsible government agencies

No.	Climate related risks	Responsible institution
1.	Increase in animal diseases	MoA
2.	Increase in crop diseases and pest infestation	MoA
3.	Biodiversity loss	MoA/IBC
4.	Land degradation	MoA
5.	Loss of soil fertility	MoA
6.	Fluctuation in water availability	MoA/MoWR
7.	Challenge on physical structures	MoA
8.	Constrained food security	MoA
9.	Disasters	MoA
10.	Enhanced GHG emissions	MoA/EPA
11.	Increase in environmental refugees	MoA/Main Department for Immigration

Source: EPACC

Bottom-up mainstreaming

An approach that relies mainly on local circumstances is likely to be sustainable. This seems to be the understanding of the Ethiopian government. The draft national adaptation programme is based on information from grassroots communities. Regional administrations are responsible for overseeing vulnerability mapping, risk analysis and adoption of identified measures within their constituency. This assignment was devolved to the regional states after the launch of the adaptation programme development back in March 2010. So far all the 11 regional states (including the two city administrations of Addis Ababa and Dire Dawa) have designed their local specific adaptation measures. The documents are in various stages and all have tried to follow an agreed-upon format to ease final consolidation. In all case, the regional documents attempt to cover the following issues:

- Overview of climate variability and change in the region;
- Vulnerabilities of biophysical resources and sectors;
- Local adaptive measures;
- Criteria for selection of adaptation measures;
- Prioritization of measures;
- Portfolio of good practices and technologies;
- Regional adaptation framework and relationship with development goals;
- Complementarity with national goals and other environmental treaties;
- Potential barriers for implementation; and
- Regional framework preparation process.

Shortfalls of the draft EPACC

The time frame for finalizing of a national adaptation programme was very short (March 2010 to July 2011), and the document has the following shortfalls:

- Lack of deep regional analysis. Given the short time frame allocated to the regional administrations, experts predominantly relied on secondary data. As such, it may not be possible to implement adaptive measures on the basis of the present document alone. However, it can serve as a basis for future analysis.
- Recent NMA data for temperature and rainfall were not used as a basis for assessment of vulnerability as the data requested was not provided in time. All assessments were made on the basis of 2007 meteorological data as incorporated under the NAPA.

- Key sectors such as the Ministry of Agriculture have not submitted their sector wide climate vulnerability assessment and priority adaptation measures as required. The agriculture sector is a major area of focus for Ethiopia and it is also the sector that is affected by climate variability. This is a problem of horizontal coordination. It is often difficult to engage parallel agencies and at best to bring on board all major stakeholders within a short time period. To address the major gaps, the team compiling regional and sectoral adaptation programmes collected raw data¹⁰ by sending missions to each of the key institutions.

Mainstreaming at project level

Before development projects are implemented, they are expected to undergo an Environmental Impact Assessment (EIA). This process involves assessing possible risks that will be caused as a result of a project. The aim of the analysis is to come with a win-win situation, by minimizing to the extent possible, any negative effects on the environment. If done properly, the EIA process will minimize unnecessary hazards that communities will be exposed to as a result of implementing a particular project (Hahn and Frode 2010).

According to Proclamation No. 299/ 2002, the EIA process demands intense consultation with the community within the vicinity of which the project is to be implemented. This gives additional avenue for incorporating ideas before projects are implemented. Two outstanding problems have been experienced since the law came into force. These include information gaps within communities about possible climate change impacts, and absence of a platform for community participation in development projects. In order to address these problems, the governance of EIA in Ethiopia was changed, and the obligation of considering climate change mainstreamed within sectoral EIA guidelines.

Currently, the sectors examining the EIA studies are obliged to report to EPA every three months. EIA guidelines specific to sectors have been revised¹¹ through the incorporation of a study on climate risks specific to the project in question and the requirements for adaptation. So every project has to follow these guidelines and come up with their own projections of

¹⁰ Interview with Ato Legesse Gebremeskel, Team leader, Compilation Team of the EPACC, on 25 June 2011

¹¹ Interview with Ato Dereje Agonafir, Director of Environmental Units at the Environmental Protection Authority, on 25 June 2011.

impacts and the possible management options. This is an important development in terms of mainstreaming climate change at project level or “climate proofing” projects.

Are sectors reporting to EPA regarding their performance on EIA? How well is the monitoring mechanism functioning? What if sectors such as the Ministry of Agriculture fail in the exercise and their obligations? Will the conferred obligations be retracted? How well are the EIA guidelines adhered to? Despite the recent developments in EIA governance, these issues still remain vague.

13.3.6 Mainstreaming climate mitigation

The government of Ethiopia has adopted an economy-wide approach to identify possible areas for mitigation. These potential areas are captured in the NAMA. The GTP of Ethiopia forecasts that agriculture will still remain an engine of economic growth in terms of providing inputs for the manufacturing sector, increasing household income, a foreign exchange earner and ensuring food security. The GTP states that over the course of the next 5 years, an estimated 8% sustained growth is expected to achieve these objectives. Despite the ambition, the sector is affected by environmental degradation and loss of soil fertility resulting from a combination of factors.

Agriculture is one of the sectors with high emissions, and high mitigation potential. From preliminary projections, it is estimated that the sector has a potential of reducing up to 80% of the total GHG emissions of the country, compared to the traditional growth pathway (EPA 2011c). The identified mitigation measures include intensification of crop and livestock production, limiting soil-based emissions from agriculture and reversing the pressure on forest land due to agricultural expansion. Priority actions include:

- Intensification of agriculture through improved inputs and enhanced residue management;
- Creating new agricultural land from degraded areas through irrigation;
- Introduction of lower emitting techniques;
- Increasing animal value chain efficiency;
- Promoting consumption of lower emitting protein sources;
- Introducing mechanical equipment for ploughing;
- Dissemination of fuel efficient cooking and baking facilities; and
- Enhancing forest management through afforestation and reforestation.

13.3.7 Shortfalls in the mitigation plan

Similar to the preparation of the national adaptation programme, the time frame for preparing the comprehensive mitigation plan was also very short. It was done within a period of slightly more than a year and was expected to be completed before the Conference of the Parties to the UNFCCC in November 2011 in Durban, South Africa. The amount of work accomplished within such a short time frame is important. In particular, it can serve as a basis for future by anyone interested in investing in agricultural mitigation activities. However, the data used to make assumptions and projections is not complete and heavily relied on data from sectors and local researchers. Specific details are therefore required to enable quality baseline data and forecast scenarios.

13.4 Conclusions

Climate change is already affecting agriculture in Ethiopia. Various attempts are being made to address climate change vulnerabilities already identified in agricultural sector as summarized in the adaptation component of the Climate Resilient Green Economy document. The agricultural sector is also recognized for its immense mitigation potential as most of the GHG emissions from Ethiopia come from agriculture. The potential measures for reducing emissions and the feasibility of realizing these constitute the green economy part of the CRGE strategy. In Ethiopia, climate change mainstreaming in agriculture and food security sectors is reflected in this document.

The document for mainstreaming climate change has its strengths and weaknesses. Its strengths are reflected in the relatively short time for its preparation, for the comprehensiveness of the work and the consultative process (both top down and bottom up approaches). The weaknesses of the strategy include its inability to use updated climate data, reliance on desktop review rather than data from the field, and failure by key sectors such as the Ministry of Agriculture in coming up with a sector specific strategy within the EPACC. The work in progress can be fine-tuned if the weaknesses above are addressed.

References

- Aplet GH, Anderson HM, Wilmer B. 2010. Managing the risk of climate change to wildlands of the Sierra Nevada. Research Paper. Washington DC: The Wilderness Society.
- CTA. 2008. Implications of climate change for sustainable agricultural production systems in ACP countries. Technical Centre for Agricultural and Rural Cooperation (CTA).
- EPA. 2011a. Climate Resilient Green Economy Mission Statement (draft). Addis Ababa, Ethiopia.
- EPA. 2011b. Ethiopian Programme of Adaptation to Climate Change (draft). Addis Ababa, Ethiopia.
- EPA. 2011c. CRGE Strategy (draft). Addis Ababa, Ethiopia.
- [FfE] Forum for the Environment. 2006. Climate change and environmental degradation: Report on the 2006 flood disaster in Ethiopia. Addis Ababa, Ethiopia.
- Hahn M, Frode A. (2010). Climate proofing for development: Adapting to Climate Change, Reducing Risk. GTZ.
- [IETA] International Emissions Trading Association. 2011. Sen. Leiberman speech at CFNA 2011. (Available from http://www.ieta.org/index.php?option=com_content&view=article&catid=19%3Adefault&id=331%3Aasen.-lieberman-speech-at-cfna-2011&Itemid=92) (Accessed on 10 June 2011)
- IPCC. 2007. Climate change 2007: Synthesis report, contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change.
- Mertz O, Halsnæs K, Olesen JE, Rasmussen K. 2009. Adaptation to climate change in developing countries. *Environmental Management* 43:743–752.
- MoFED. 2011. Growth and Transformation Plan. Addis Ababa, Ethiopia.
- [NMA] National Meteorological Agency. 2007. Climate change National Adaptation Program of Action (NAPA) of Ethiopia. Addis Ababa, Ethiopia.
- Saka A. 2008. Global warming and the impacts of climate change on vulnerable communities and sectors of economic growth. Paper presented at the 2nd ANAFE International Symposium on “Mainstreaming Climate Change into Agricultural and Natural Resources Management Education: Tools, Experiences and Challenges” Held at Capital Hotel Lilongwe, Malawi from the 28th July to 1st August 2008.
- Stern N. 2006. Stern review on the economics of climate change. London: HM Treasury.
- UN. 2009. World population to exceed 9 billion by 2050. Press release. (Available from <http://www.un.org/esa/population/publications/wpp2008/pressrelease.pdf>)

14. Uneven terrain: Gender gap in Ethiopia's agricultural sector

Oxfam¹²

Abstract

This paper documents empirical evidence from three Ethiopian regions, focusing on three issues that have received much attention in the gender debate: labour contribution by women in rural livelihoods including specific labour contribution to agriculture, gender productivity gap, and to what extent do women farmers face discrimination in accessing production resources. The study also explores the existing gender policies and laws, and assesses their effectiveness in improving the livelihoods of women smallholder farmers.

The study was carried out in three regions of Oromiya, Amhara and Southern Nations, Nationalities and Peoples Region (SNNPR). One district was selected from each region representing different agro-ecologies and farming systems. The selected districts included Adami Tulu Jido Kombolcha (AT-JK) district in East Shewa zone of Oromiya region, representing irrigation supplemented mixed crop-livestock farming systems; Ankober district from North Shewa zone of Amhara region, representing rainfed mixed crop-livestock farming systems; and Wenago district from Gedeo zone of SNNPR, representing rainfed coffee-enset-root crops farming system.

The study used qualitative and quantitative methods. The qualitative techniques used included participatory semi-structured interviews and focus group discussions. Information was also obtained from relevant national policies, research reports, programme documents, and

¹² Reprinted with permission from Oxfam. Oxfam acknowledges that this synthesized paper is based on commissioned research conducted by Management Consultancy Firm, in November 2010 by researchers Agajie Tesfaye and Derese Teshome. Oxfam also acknowledges the support of Almaz Woldetensay.

This report paper was compiled by Gina Castillo, Tigist Gizaw, Emmanuel Tumussime, and Alivelu Ramisetty, and with contributions from Yeshimebet Gemeda and Selome Kebede. The research was conducted by Agajie Tesfaye and Derese Teshome. It is part of a series of research reports written to inform the public debate on development and humanitarian policy issues. The views expressed in the text and its recommendations are those of the authors. The authors take responsibility for any errors herein.

databases. Quantitative data was collected through household surveys using a structured questionnaire.

Data were collected from a random sample of 328 households, generated from a stratified sample in three districts: 108 households from AT-JK, 108 from Ankober and 112 households from Wenago districts. Out of the total sample of 328 households, 69% were male headed households (MHH) while 31% were female headed households (FHH). Descriptive statistics were derived and used for making inferences.

Keywords

Gender productivity gaps; labour; agriculture.

14.1 Introduction

Alo Mohammed, a 50 year old woman farmer and a mother of 6, from the central rift valley¹³ of Ethiopia says “My husband and I used to work together to make ends meet. But after he passed away, all the responsibilities of the household fell on my shoulders and life became more difficult. I could not plough the land for fear that I would bring drought, hail or all sorts of evils”. The only option Alo saw for herself was to lease her land to a cultivator on the basis of “equal share of the produce”. She received half of the produce. But this share would drop significantly when drought came, an all too frequent occurrence in this area. Alo then realized that she had two choices: to break the taboo or to live in hunger with her children.

Alo’s story is similar to the story of millions of small-scale women farmers throughout Ethiopia, who face immense barriers to produce food for their families. Cultural norms and poor access to productive resources makes it difficult for women farmers to grow food. In many communities throughout Ethiopia, what women do is not considered to be “economically active work”, and in some instances, even by the women themselves. Yet the work of women is essential to the wellbeing of the households and to the wider economy.

Although policymakers in Ethiopia acknowledge the importance of smallholder women farmers and have put in place appropriate policies to improve their wellbeing, there is limited evidence on the actual contribution of women to agriculture. To contribute to the gender debate and to spur more discussions, Oxfam commissioned this research in three regions in Ethiopia, focusing on the following four questions:

- How much of the agricultural and domestic labour is performed by women?
- To what extent do women farmers face discrimination in accessing productive resources in Ethiopia?
- What is the productivity gap between men and women farmers in Ethiopia?
- Which laws and policies have been designed to improve the livelihood of women smallholder farmers and how are these laws and policies being implemented?

The overall aim is to provide a greater understanding on the barriers women farmers’ face, so as to devise appropriate actions to eliminate the barriers.

¹³ Adami Tulu Jido Kombolcha district of Oromiya National Regional State

This paper is organized into five sections. Section one provides an overview of the study sites and a description of the methodologies used. Section two presents the contribution of men and women to the agricultural sector, highlighting the roles played by men and women in farming and the extent of contributions under different agro-ecologies and farming systems. The third section examines the gender gaps that persist in accessing public services (such as access to extension, credit, information and other services), and resource ownership and also reasons behind these gaps. Section four provides an analysis of the gap in crop productivity between men and women farmers. Section five gives an overview of the policies in place to promote women's empowerment and gender mainstreaming. Finally, the paper concludes by presenting recommendations for policy makers, development actors and other relevant partners to reduce the gender gap in agriculture.

14.2 Study areas and methodology

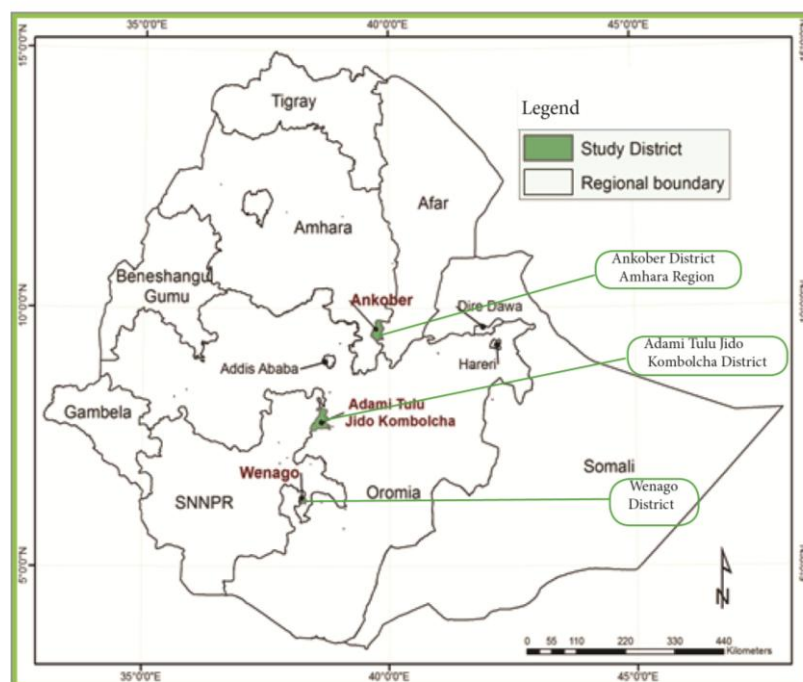
Data for this report were collected from three districts in Oromiya, Amhara and Southern Nations Nationalities and People Regions (SNNPR). One district was selected from each of regions for detailed data collection and analysis (Figure 14.1). A description of the study areas is summarized in Table 14.1.

The study used both qualitative and quantitative methods. Qualitative techniques included semi-structured interviews, focus group discussions and open ended interviews with key informants in the districts. Questionnaires were used as part of the quantitative technique. Districts were stratified into different agro-ecologies and farming system types. From the selected agro-ecologies and farming system types, Farmer Associations (FA) were selected in consultation with the Ministry of Agriculture staff. In total, six FAs were selected from each of the three districts and a total sample of 328 households was drawn (112 from Wenago district and 108 each from AT-JK and Ankober).

Table 14.1. Descriptions of the case districts

District	Sample Kebeles	Location and distance from Addis Ababa	Elevation (masl)	Type of climate and terrain	Population (CSA, 2010)	Type of farming system
Adami Tulu Jido Kombolcha	Abinee Garmaama, Qamo Garbi, Galo Erepe, Dodicha, Negalign, Walinbula	Oromiya region, Rift Valley, 163 Kms south of Addis Ababa	1700 - 2000	Semi-arid/dry, hills and lakes	167,066	Irrigation supplemented mixed crop-livestock farming
Ankober	Lay Gorebela, Aliu Amba Zuria, Mesabitna Badima, Washa, Gorgo, Hagere Selam	Amhara region. 171 Kms north east of Addis Ababa	1800 - 3200	Semi-arid, mid- altitudes and highlands	94,090	Rainfed mixed crop crop- livestock farming
Wenago	Kelecha, Bank Okoto, Hase Haro, Kara Sodity	SNNP region, 371 Kms south of Addis Ababa	1600 - 1800	Moist to sub-humid	285,983	Rainfed coffee-enset- root crops based farming

Figure 14.1. Map of the study areas



The sample was stratified into male headed households (MHH) and female headed households (FHH). Out of the total sample of 328 households, 69% were MHH and 31% were FHH. The MHH was further sub-divided into categories of husbands and wives. Of the 69% MHH, 35% were husbands and 34% wives. During sampling, the husband and wife were drawn from different households. Household interviews were then conducted with the wives. Supplementary information was also collected through focus group discussions and interviews with key informants from the following sector: agriculture, women, children and youth affairs, police, justice, education, and health. Microfinance institutions (MFIs) and non-governmental organizations (NGOs) operating in the study areas were contacted to obtain supplementary information related to the study.

14.3 Gender roles in smallholder agriculture

This section examines the labour contribution of men and women to agriculture and domestic activities in the study sites. The results are summarized and presented in Table 14.2.

Table 14.2. Labour contribution to farming and household activities by men and women during peak seasons

District	Total time spent on farming and domestic activities (hrs/day)		Percent of contribution to agricultural family labor		Proportion of time devoted to domestic activities (%)	
	Men	Women	Men	Women	Men	Women
Adami Tulu (AT-JK)	11	16	62	38	10	90
Ankober	12	16	62	38	17	83
Wenago	10	12	75	25	10	90
Overall sample	10	14	65	35	11	89

Source: Authors 2011

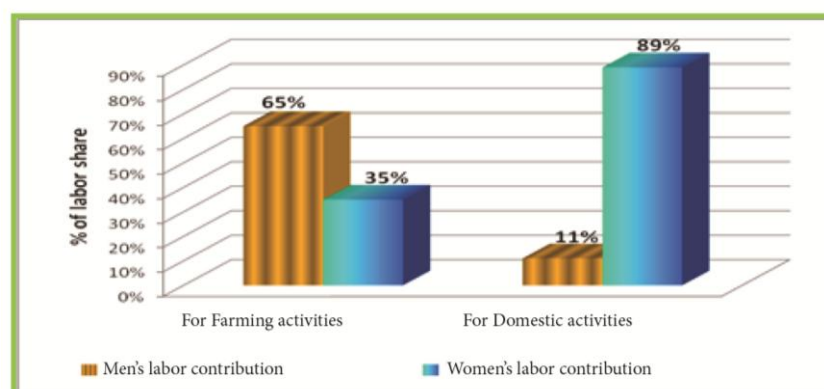
A number of observations are important to highlight from Table 14.2. In the irrigation supplemented and rain-fed mixed crop-livestock farming systems of AT-JK and Ankober districts, women spent on average 16 hours a day in both farming and domestic activities compared to 11–12 hours spent by men. In the coffee-enset¹⁴ based farming systems of Wenago, women spent 12 hours on average compared to 10 hours spent by men. Thus from the overall sample, women spent on average 4 hours more in a day than men on both farming and domestic activities. The average time women spent on agriculture is the same for AT-JK and Ankober case districts and farming systems. In Wenago district, a coffee-enset based farming systems in SNNPR, women contributed 25% of their labour to agriculture. In this perennial crop system, men do most of the activities. Therefore, routine activities that demand women's labour is less in coffee-enset farming systems than the other types of farming systems covered by the study.

Across the three districts, on average, women's contribution to agricultural production accounted for 35% of the total agricultural labour while 65% of the labour came from men. The contribution of women's labour to agriculture is in addition to their domestic

¹⁴ Enset is a plant that resembles banana in appearance and its scientific name is: *Ensete verticosum*. It is single stemmed (pseudo stem), monocarpic, perennial and herbaceous plant. It grows up to 7 m in height depending on clone type and management. It is one of the major food crops in southern Ethiopia.

responsibilities. In the case studies, 89% of the domestic responsibility is done by women while the remaining 11% is covered by men (Figure 14.2). Thus, the overall burden of domestic labour is on women than men.

Figure 14.2. Contribution of men and women’s labour for farming and domestic activities



Source: Authors 2010

The case studies in the three agro-ecological zones show that indeed the agriculture sector is uneven terrain for women in terms of labour contribution.

14.4 Measuring access to productive resources

Field reports and previous studies have pointed to the existence of gender gaps in access to and utilization of agricultural production resources. These gaps have been identified as limiting small-scale women farmers’ productive capacity. One significant constraint that affects women’s ability to increase yield and productivity is unequal access to resources. Often agricultural extension service strategies have focused on providing men with training, information, technology and access to inputs and credit. Women have limited access to land ownership and have insecure land tenure systems. Land titles are held by their fathers, brothers, husbands, sons or other male family members as per the customary law. In the case of female headed households, the women often own land which is marginal and very small. Thus, the existing unequal rights owing to cultural and religious discriminatory laws have a negative impact of women farmers’ productivity. Often female headed household have less land and labour than male headed households.

In Ethiopia, the extent of these gaps is not well understood, which in turn affects policy planning and resource use. Hence, it is important to look at women’s access to key resources.

In this study, access refers to the ability of a rural woman to get socio-economic resources and accrue benefits from them. The study examined the following resources:

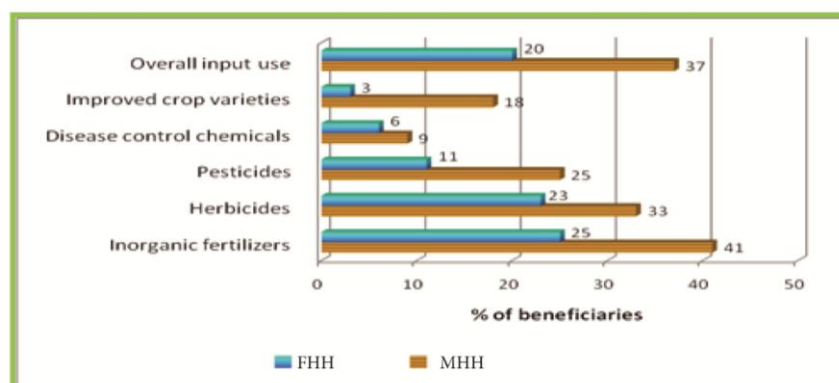
- *Access to agricultural technologies and production inputs:* Availability of cost-effective and appropriate technologies for production, post-harvest and household tasks. These technologies include improved varieties and breeds, artificial insemination, vaccines, among others. Technological inputs refer to the availability of quality seeds, saplings, fertilizers, pesticides and water supply.
- *Access to extension services and training:* Opportunities to develop technical skills for production through training and obtaining information on development aspects from any extension agency.
- *Access to land and livestock resources:* Power to use family farmland, ownership of land and control over it, opportunities to rear goats, cows, chickens and other types of livestock as income generating activities (IGA).
- *Access to capital:* Opportunity to get loans, microcredit and banking services from any formal or informal institution.

14.4.1 Gender gaps in access to agricultural technologies and production inputs

To enhance agricultural production and productivity, governmental institutions and NGOs have introduced and promoted improved crop varieties, fertilizers, herbicides, pesticides and disease control drugs. However, a noticeable gender gap was observed in women's access to these inputs in the study areas.

In rain-fed mixed crop-livestock farming systems in Amhara region and coffee-enset based farming systems in SNNPR, there is a significant gap in access to agricultural inputs for MHH and FHH. For instance, 41% of MHHs benefited from fertilizers as compared to 25% of FHH (Figure 14.3). In addition, 18% of MHHs had access to improved crop varieties as compared to 3% of FHHs. The overall sample in the three farming systems shows that 37% of MHHs had access to different agricultural inputs as compared to 20% of FHH.

Figure 14.3. Gender gaps in the access of households to agricultural inputs



Source: Authors 2010

14.4.2 Gender gaps in access to information and extension services

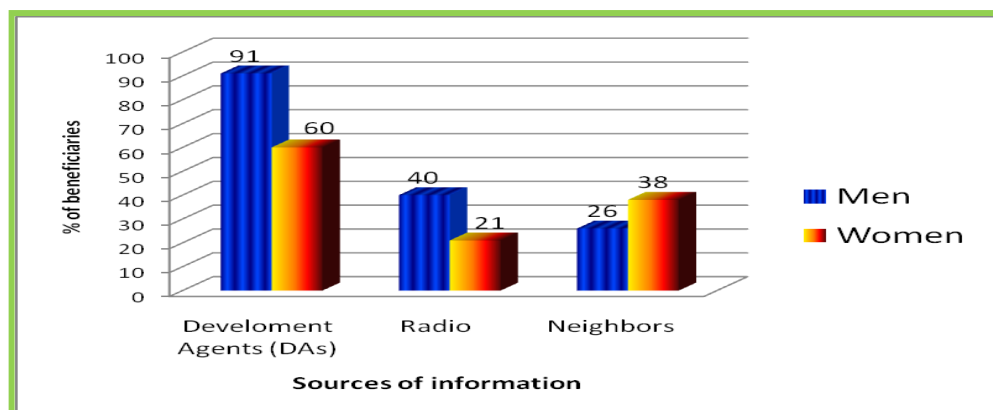
A core part of the Ethiopian government’s investment in agriculture has been the public agriculture extension system. For rural farmers, the focal point is the Farmers Training Centre (FTC) that exists at the *kebele* level. An FTC is staffed by 3 development agents (one each in the areas of crop, livestock, and natural resource management). It is at the FTC where farmers receive information, training, demonstrations, and advice. Some studies have shown that extension programmes pay little attention to gender.¹⁵

In the study zones, findings from the household surveys indicated that the most important sources of information on modern farming were development agents (DAs), neighbours and radio, in order of importance (Figure 14.4). About 91% of men receive information from DAs as compared to 60% of women. Women tend to rely on their female neighbours for information as compared to than men.

The research findings indicated that 87% of men had access to extension services as compared to 64% of women (Figure 14.5). Women who are wives have slightly more access to extension services than FHH which have 61%. Overall, access to agricultural extension in the study region is at about 70%.

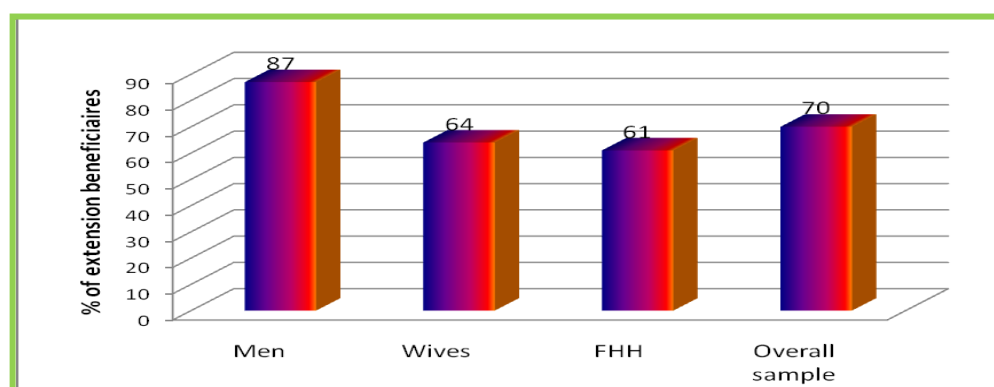
¹⁵ Other issues that are ignored are culture, youth, HIV/AIDS prevalence, agroecosystem variance. See Davis, Kristin et al. “In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendation for Improvement”. IFPRI discussion Paper 01041 December 2010. <http://www.ifpri.org/sites/default/files/publications/ifpridp01041.pdf> (Feb. 20, 2012)

Figure 14.4. Sources of information on modern farming for men and women, 2010



Source: Authors 2010

Figure 14.5. Average access to extension services in all the study locations by men and women, 2010



Source: Authors 2010

The case studies also indicated that men had better access to agricultural trainings than women. On average, 62% of men had access to agricultural extension trainings as compared to 37% of women. In Ankober, 70% of men had access to agricultural trainings as compared to 51% of wives and 50% of FHH (Table 14.3). In Wenago district, 53% of men had received agricultural trainings as compared to 30% of wives and 17% of FHH. In Ankober district, farmers had received agricultural trainings at least once a month while farmers of Wenago district had received it once in three months. Regular sessions covered new methods of agricultural management, such as improved crops and livestock technologies with associated packages, irrigation practices, soil and water management practices, poultry, beekeeping, and animal fattening. In addition, there were cases of farmers having received urgent trainings on timely harvesting and managing disease outbreaks.

Table 14.3 provides an overview of participation of men and women and illustrates the differences over a year in Ankober and Wenago districts.

Table 14.3. Participation of men and women in different types of extension events

Extension events	Percent of households					
	Ankober district			Wenago district		
	Men	Wives	FHHs	Men	Wives	FHHs
Agricultural trainings	70	51	50	53	30	17
Experience sharing visits	27	5	6	16	5	3
Farmers' field days	8	0	3	13	3	3
Participation in public service committees	49	11	12	38	11	13

Source: Authors 2011

According to the DAs, fewer women participated in the extension events compared to men because women were pressed for time due other household chores. The DAs also expressed doubts as to whether women actually use the information they received because of their low literacy levels and low attendance at public meetings and events.

The focus group discussions with women on agricultural extension system indicate that there were a limited number of DAs available and they lacked the time to reach all the farmers in one season, especially women farmers. For instance, 14% of wives in Ankober and Wenago districts, and 20% of FHHs in Wenago district indicated that DAs did not have time to visit them. A high turnover rate of DAs was also reported in the study areas. The DAs who were available on duty were over-burdened trying to cover the responsibilities of departing DAs. Women also voiced their preference for female DAs. However, the number of female DAs is low even at district level. For instance, out of the total DAs in the three districts, 87% of them were male DAs while only 13% of them were female DAs. Table 14.3 also shows that few women participate in public committees. In both Ankober and Wenago districts, 44% of overall men participate in different types of public service committees as compared to 12% of women. This allows men to gain access to new ideas and information. By not being active in public functions, women lose out in accessing new ideas.

In general, even though the agricultural extension system in Ethiopia is reaching farmers, large proportions of women are not benefiting. The current extension system is not designed

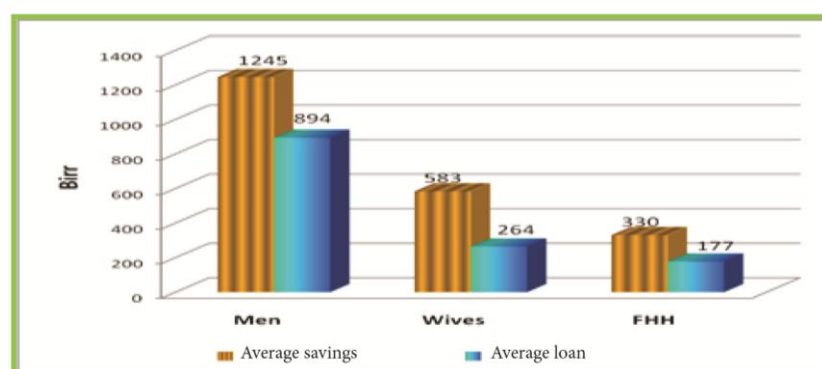
to take into account women’s economic capacity, literacy levels, domestic workloads, and the entrenched social norms which ascribe women to be silent in public and keep them at home.

14.4.3 Gender gaps in access to capital

Credit services are of paramount importance to improve agricultural productivity. The results indicated a small gap exists in access to credit, where 48% of men had access to credit services as compared to 41% of women. The two most common sources of credit were microfinance institutions (MFIs) and relatives/friends. MFIs are open to men and women so long as they fulfil certain requirements. In MHHs, both the husband and the wife are required to sign the loan agreement. FHHs can also have access to credit services as long as they provide sufficient guarantee.

MFIs use different mechanisms to encourage women, especially FHHs, to access credit services. For instance, for women group insurance, the number of group members required was downsized from five to three. Moreover, women are given priority in the application processing. These measures were incorporated following a number of community platforms designed to encourage women to access MFIs. Although access to capital is less of an issue for women in these study areas, two important issues stand out. First, average annual savings for women was lower than men. As summarized in Figure 14.6, the average savings of men (Birr 1245) was higher than that of wives (Birr 583) and FHH (Birr 330).

Figure 14.6. Average savings made and loans taken by men and women (in ET Birr)



Source: Authors 2010

Women spend most of their earnings on food and other domestic needs, while men save most of their earnings for perceived future security. In addition, the average annual loan taken by

men was higher than the loan taken by wives and FHHs. The average annual savings and loan taken was higher for wives than FHHs. Wives often use the loans for income-generation activities such as petty trading. The low saving by FHH is mainly due to their low resource ownership, and also they have to shoulder all the household financial responsibilities. FHHs do not have extra money to save. Education, application procedures, access to land, income level, farm size, cooperative membership, amount of savings, type of crops, interest rates offered, distances to the credit institution in addition to the socio-economic and institutional factors all influence access to credit for women (wives and FHHs) in small holder agriculture.

14.4.4 Gender gaps in access to land and livestock resources

In households where agriculture is the primary occupation (both in MHHs and FHHs), land is a basic source of livelihood providing employment, a key agricultural input and a major determinant of access to other productive resources and services. Since land is the main source of income, women's lack of access and ownership to land results in their lower economic status. Findings from this study show that FHHs had lower levels of resource ownership than MHHs. The average size of farm land owned by MHHs (1.1ha) is higher than FHHs (0.8ha) as summarized in Table 14.4. Gender disparity in land ownership is higher in AT-JK than Ankober and Wenago, where it appears less perverse. Also, MHHs own more livestock (2.61 TLU¹⁶) than female headed households (1.82 TLU; Table 14.5).

¹⁶ One Tropical Livestock Unit (TLU) = 250 kg of an animal.

Table 14.4. Average farm sizes per household (ha) in the case districts

District	Male headed households		Female headed households		Total	
	N	Average farm size (ha) per household	N	Average farm size (ha) per household	N	Average farm size (ha) per household
Adami Tulu (AT-JK)	70	1.8	38	1.2	108	1.6
Ankober	73	0.9	34	0.7	107	0.8
Wenago	80	0.6	30	0.4	110	0.5
Overall sample	223	1.1	102	0.8	325	1.0

Source: Authors 2011

Table 14.5. Gender gaps in livestock ownership

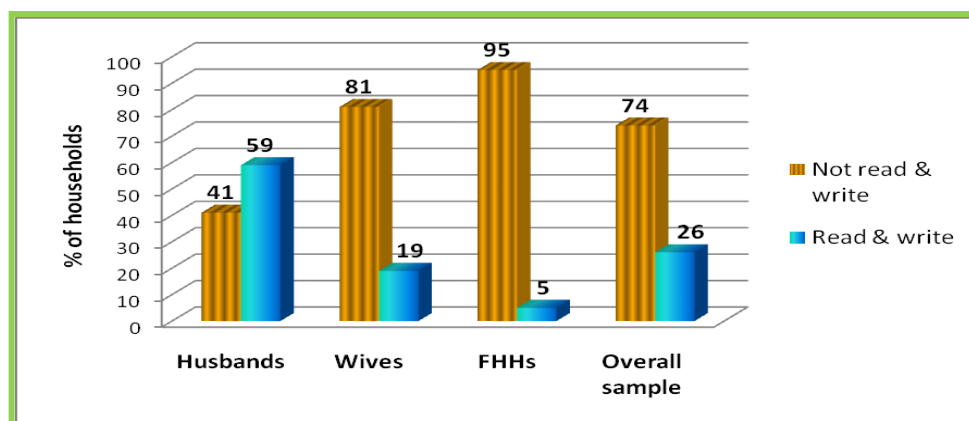
District	Male headed households		Female headed households		Total	
	N	Average TLU	N	Average TLU	N	Average TLU
Ankober	71	3.52	29	2.14	100	3.12
Wenago	45	1.18	10	0.91	55	1.12
Overall sample	116	2.61	39	1.82	155	2,41

Source: Authors 2011

14.4.5 Gender gaps in literacy levels

Literacy levels are closely associated with women's ability to access information and improved technologies. The various perspectives of gender gaps presented in the previous sections were also partly attributed to lower literacy levels of women. As shown in Figure 14.7, the findings from all study sites indicate a wide literacy gap between men and women: 74% of men were literate as compared to only 26% of women. This was mainly attributed to cultural barriers dating back 20 years ago, which discouraged girls from attending school and instead encouraged them to get married at a very young age (12–15 years old). In recent years, the government has increased its efforts to improve access to education for both boys and girls. Accordingly, the literacy level of children and youths above the age of seven in the study areas was 89%. Yet, 50% of the literates were boys while only 39% were girls.

Figure 14.7. Educational level of sample households



Source: Authors 2010

14.5 Productivity gap between men and women farmers

Until now, we have seen that women farmers in the study areas have limited access to technologies, low literacy, less capital, and limited access to agricultural extension services. How does this affect productivity? The study points to lower agricultural productivity for women than their male counterparts (see Table 14.6). For instance, in Ankober and Wenago, the average productivity of MHHs for maize was 14 quintals/ha compared to only 6 quintals/ha for FHHs (Table 14.6). This implies that FHHs produced 57% lower yield of maize than MHHs. A productivity gap of 38% and 25% were observed between MHHs and FHHs in teff and wheat production, respectively.

Table 14.6. Productivity gap of major crops for male and female headed households

Crop	Male headed households		Female headed households		Percent of yield gap
	N	Average yield (qt/ha)	N	Average yield (qt/ha)	
Maize	63	14	15	6	57
Teff	61	8	21	5	38
Wheat	15	8	8	6	25

Source: Authors

As mentioned above, women farmers have limited access to information, technology, land, inputs and credit. Also, agricultural support services are generally provided by men who are not always aware of the specific problems and needs of women farmers. Information and extension services are typically geared towards male farmers, on the assumption that the message will trickle to women. The reality is that this does not happen.

14.6 Gender in the policy arena

Incorporation of gender in development programmes and policies is fundamental to enhance agricultural productivity in the context of climate variability and change. This section reviews the legal policy frameworks and national policies and plans that the Ethiopian government has put in place to promote gender within its overall economic and development agenda.

14.6.1 Gender in the Ethiopian constitution

Article 35 of the Constitution of Ethiopia recognizes equal rights to women and men in resource ownership and access to public services. Sub-article 35.6 of the Constitution states, “Women have the right to full consultation in the formulation of national development policies, the designing and execution of projects, and particularly in the case of projects affecting the interests of women” (Ethiopian Constitution 1995). According to sub-article 35.7, women also have the right to acquire, administer, control, use and transfer property. Thus women have equal rights with men to use, transfer, administer and control land. They also have equal right to inherit property.

The National Policy on Ethiopian Women published in 1993 facilitates equal participation of women in all political, economic and social spheres. It proposed a structure in government offices and institutions so that all public policies and interventions would be gender-sensitive and ensure equitable development for both men and women. In 2002, the government created the Ministry of Women’s Affairs, currently known as the Ministry of Women, Children and Youth Affairs (MWCY).

14.6.2 Gender in the national development policies and strategies

In the national policies and strategies of different ministries and organizations such as the Ministry of Finance and Economic Development (MoFED), Ministry of Agriculture and Rural Development (MoARD), Ministry of Women, Children and Youth Affairs; Environmental Protection Authority (EPA); and Ethiopian Institute of Agricultural Research (EIAR) women are recognized as farmers. Ethiopia’s Plan for Accelerated and Sustained Development to End Poverty (PASDEP)—the country’s five year (2005/06–2009/10) development plan—acknowledges the role of gender equity in development processes (MOFED 2006). In fact, one of the eight pillars of the strategic plan was to unleash the potential of Ethiopia’s women through a wide range of programmes designed for women

including agricultural extension, microcredit, natural resource management, and small business promotion. Compared to the condition before the PASDEP programme, some improvements have been made. Women are being involved in extension services and encouraged to get easy access to microcredit services. Other improvements include higher participation of women in natural resource management and small scale businesses.

In the new five year plan—the Growth and Transformation Plan (GTP) (2010/11–2014/15)—one of the seven strategic pillars is on women and youth empowerment and equitable benefits (MoFED 2010b). GTP places gender as a cross-cutting issue and seeks to ensure women’s participation in the economic sector programmes and extension packages. In the agriculture section of PASDEP, the target beneficiaries have no gender disaggregation. However, in the GTP, the envisioned number of beneficiaries of the agricultural extension services has been gender disaggregated, and the goal is to increase the proportion of women extension beneficiaries to 40% by the end of the GTP period.

In line with the GTP, the five-year plan of the EIAR treats gender as a cross-cutting issue. It states “gender dimensions will be incorporated at different stages of research processes, such as problem identification, technology generation and verification, promotion and extension of agricultural technologies, capacity building and others” (EIAR 2007).

14.6.3 Women affairs directorates and gender focal offices

To ensure gender mainstreaming, ministries, organizations and institutions established Gender Desks, Gender Based Directorates and Gender Coordination Offices. The MoARD, for example, created a Directorate to address gender issues. The purpose of the Gender Directorate is to build the capacities of all the staff and management bodies on gender, to advise them on how to mainstream gender, and to monitor and evaluate the implementation of gender development programmes, projects and activities at the grassroots. The Ministry of Women, Children and Youth Affairs (MWCYA) has a Gender Mainstreaming Department responsible for coordinating gender mainstreaming in ministries, authorities, organizations and institutions. At the lower government level, Gender Desks and Gender Focal Offices exist to mainstream gender in their respective organizations and institutions. Some institutions have a gender advisor at their grassroots branch offices to support gender mainstreaming in projects and activities.

When the research team interviewed both male and female staff from the Directorates and Offices to ascertain their opinion on how this structure was functioning, they acknowledged that a lot remains to be done. They mentioned that Gender Directorates were responsible for preparing mainstreaming guidelines, but these had yet to be produced. There is also limited capacity on the practical skills of gender planning, gender mainstreaming, and gender budgeting, as well as gender monitoring and evaluation. In some offices, this gap was attributed to inadequate financial allocation to the Gender Directorates and Gender Offices. Other reasons mentioned included the attitude of staff, especially men in ministries, inadequate commitment and support from different levels of management in various ministries, and the unavailability of gender mainstreaming guidelines in most of the offices.

Even though gender is recognized in the constitution of Ethiopia and a framework has been created to address gender issues, a gap exists in translating policies into action. It is necessary to eliminate this gap so that women can benefit from the investments in the agriculture sector.

14.7 Conclusion and recommendations

This study shows that the contribution of women to the agricultural sector is considerable. On average, women spend about 14 hours doing domestic and other productive activities compared to 10 hours spent by men. Women's contribution to agricultural production accounted for 35% of the total agricultural labour while 65% of the labour came from men. Even though women make significant contributions to the agricultural sector of Ethiopia, a wide gap exists in access to agricultural extension, financial and education services. Wide gender gaps were also observed in access to agricultural technologies and resource ownership. All these have resulted in lower productivity levels by small-scale women farmers as compared to their male counterparts. To reverse this situation and to ensure a dignified life for women farmers, the study recommends the following actions for closing the gender gap:

- *Change attitudes of the community on taboos on gender and gender equity:* At the community level, there are taboos that limit women's participation in agricultural activities. For instance, it is still considered a taboo by both men and women that if women plough, some evil event such as hail, drought can happen. To break these taboos, a range of approaches should be tried and experimented with—plays, trainings among others—to target both men and women. Visits to areas that have broken such taboos

should be arranged. School curricula needs to include gender equity to change belief systems from an early age.

- *Design women friendly and gender responsive agricultural extension systems:* The extension services have to respond to the needs of women farmers. More women need to be encouraged to become DAs to increase numbers, which are currently low. The curriculum for becoming a DA needs to incorporate gender to change perception and attitudes, and to sensitize potential DAs on the unique constraints that women farmers face. Also, literacy training needs to be included as part of Farmers' training to increase the literacy level of women.
- *Introduce village level access to financial services and saving practice for women:* Women highlighted that they prefer to get credit services from their own savings. Village level microfinance institutions need to be established and promoted especially for women, through the creation of village saving and loan groups (VSLGs) where women can save their own earnings and get credit from them. An advantage of this system is that collateral is not required.
- *Promote the organization of women into associations of common social and economic interests and vision:* Women have limited capacity to exercise their right when they act individually. In a focus group discussion with the women, they expressed a desire to organize themselves into groups of common interests both for economic and social purposes. A group approach is essential for accessing and promoting technology and to access public services. It is also a powerful way to begin to challenge cultural norms and to influence public decisions.
- *Enhance capacities of technical staff and management bodies at various levels on gender in agricultural development:* A serious capacity gap exists at various levels on the practical skills of gender mainstreaming on specific programmes, projects and activities. Therefore, it is essential to enhance capacities on practical skill such as gender mainstreaming, gender planning, gender budgeting, gender monitoring and evaluation, and other aspects.

References

- Central Statistical Authority. 2010. The 2007 Population and Housing Census of Ethiopia.
- Constitution of the Federal Democratic Republic of Ethiopia. 1995. Federal Negarit Gazeta of the Federal Democratic Republic of Ethiopia. Addis Ababa: Government of Ethiopia.
- [EIAR] Ethiopian Institute of Agricultural Research. 2007. New research strategy and business process re-engineering.
- Food and Agriculture Organization. 2011. The state of food and agriculture: Women in agriculture—closing the gender gap for development.
- Institute of Development Studies. 2010. Gender and development: Concepts and definitions.
- [MoFED] Ministry of Finance and Economic Development. 2006. A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10). Addis Ababa, Ethiopia. Volume I: Main Text.
- [MoFED] Ministry of Finance and Economic Development. 2010a. Performance of the First Five Year Development and Plan of the new Growth and Transformation (2010/11-2014/15). Addis Ababa, Ethiopia.
- [MoFED] Ministry of Finance and Economic Development. 2010b. Growth and Transformation Plan (2010/11-2014/15). Addis Ababa, Ethiopia.
- Mogues T, Cohen MJ, Birner R, Lemma M, Randraimamonjy J, Tadesse F, Paulos Z. 2009. Agricultural extension in Ethiopia through a gender and governance lens. International Food Policy Research Institute (IFPRI) and EDRI. Addis Ababa, Ethiopia. Discussion Paper No. ESSP2 007.
- Spees P. 2004. Gender justice and accountability in peace support operations. International Alert. (Available from <http://www.un.org/womenwatch/osagi/feature/postconflict/gender%20justice-international%20alert.pdf>) (Accessed on April 2012)
- Tesfaye A, Teshome D. 2010. Assessing the potential role of small-scale women food producers in a climate smart agricultural development in Ethiopia: A case study. Addis Ababa, Ethiopia: Management Consultancy Firm.
- Tiruneh A, Tesfaye T, Verkuiji H, Muangi W. 2000. Gender differentials in agricultural productivity among smallholders in Ada, Lume and Gimbichu Woredas of the Central Highlands of Ethiopia. In: Institutionalizing gender planning in agricultural technology generation and transfer processes. EIAR: 92–105.

15. Conclusion and recommendations

The papers from this conference have shown that climate change is already affecting Ethiopia and its impacts will continue to worsen in the future if adaptation strategies are not enacted. Low agricultural productivity and recurrent food insecurity have already put the country in a precarious situation, which will only be exacerbated by climate change and variability. Improving food security in rural and urban areas is a major challenge for Ethiopia, and the impacts of climate change will make this an even more difficult task. As Nega points out in his paper in Chapter 4, a large majority of smallholder farmers are already affected by climate-related hazards. Climate change may cause greater scarcity of natural resources, which can trigger competition among individuals and communities, as highlighted by Dalle in Chapter 7. Desta provides evidence in Chapter 8 that climate change in the Borana pastoral area has already been affecting pastoralists for decades. Rainfall amounts have declined and become more erratic, and temperatures have increased. The Borana and other pastoral groups, who own and manage significant proportions of the livestock herd countrywide, are particularly vulnerable to climate change, according to Tegegne in Chapter 11.

The 13 papers presented here offer common themes of priorities to effectively address climate change in Ethiopia. These common themes are:

- Improved policies and climate change policy mainstreaming;
- Enhanced coordination, cooperation and collaboration;
- Capacity building;
- Addressing research and knowledge gaps;
- Increased investment and funding;
- Involvement of local communities; and
- Enhanced agricultural extension services.

Focusing on these priority areas will help the country tackle the enormous challenges of climate change.

Improved policies and climate change policy mainstreaming

Many papers recommend the formulation or improvement of policies regarding climate change and mainstreaming of climate change policy within other sectors, especially agriculture. Among these are Dalle's paper on transboundary issues in East Africa, Desta's paper on transition in Borana livelihoods, Tesema's paper on agrobiodiversity, and Tegegne's paper on the livestock sub-sector. Mainstreaming is specifically addressed in Sintayehu's paper on mainstreaming of climate change policies.

Dalle concludes that East African countries, including Ethiopia, need to improve governance in maintaining stability and security by ensuring broad-based development, building strengthened institutional architecture and regional cooperation, and improving disaster preparedness to reduce climate change impacts. He recommends improved policies for sustainable development of transboundary natural resources and harmonization of international legal provisions with national legal provisions.

Both Desta and Tegegne recommend policies that facilitate livestock mobility, including removing obstacles constraining mobility to help preserve the pastoral way of life. It will become increasingly critical for pastoralists to be able to move their herds to access dry season pastures and water as rainfall becomes more erratic and unpredictable. Desta also recommends policies that assist the introduction and adoption of improved range management, water development and dryland farming techniques to help the Borana adapt to the changing climate. A final recommendation from Desta is the need for policies that pave the way for engagement of the Borana in urban income-generating activities to help them become more integrated into the market economy.

Tesema's paper on agrobiodiversity also provides a policy recommendation and concludes that strategies and policies for the promotion and conservation of indigenous crops should be enacted. This will help preserve farmer-selected crop varieties and livestock breeds that could be used in agricultural research to create new varieties with traits for adapting to climate change, such as drought tolerance or pest resistance. She refers to mainstreaming by recommending that agrobiodiversity should become a basic component of adaptation strategies to climate change.

Sintayehu describes the process through which a document on mainstreaming climate change policy was developed and highlights some weaknesses that ought to be addressed within the strategy. One weakness is the inability to use updated climate data to inform the strategy, which could be solved through capacity building of key stakeholders. Another weak point is the document's reliance on desktop work instead of data from the field—a limitation that could be resolved with more involvement of local communities.

Enhanced coordination, cooperation and collaboration

Papers recommending enhanced coordination, cooperation and collaboration are Teklewold et al. (Chapter 2 on crop production), Gissila (Chapter 6 on agrometeorological services), Eshetu (Chapter 9 on forestry and agroforestry), and Oxfam (Chapter 14 on gender). Teklewold et al. recommend the development of a strong network and partnership between the various concerned institutions to coordinate efforts and achieve progress based on climate information. Gissila advises that improvements in providing enhanced agrometeorological services to Ethiopian farmers and improvement in the knowledge of climate variability, trends and the downscaling of climate change projections and scenarios both require closer collaboration between the Environmental Protection Authority (EPA), the National Meteorological Agency (NMA), regional agricultural bureaus, agricultural research institutes, universities, and the Ministry of Education. Eshetu proposes to improve coordination by creating a system that intersects development, education, research sectors and other key development partners to improve forest management in the country. He also suggests the creation of an interface between research, science and policy to avail research outputs for policy makers. This kind of interface is critical to help translate research findings into action.

A slightly different recommendation for cooperation comes from Oxfam. One of their final conclusions is to promote the organization of women into associations of common social and economic interests to enable them to access new technologies and public services. This type of local cooperation is just as important as collaboration at the upper-most levels of government.

Capacity building

Many authors recommend capacity building of various stakeholders to help Ethiopia adapt to climate change. On an individual level, Oxfam recommends the enhancement of capacities of

technical staff and management bodies at various levels on gender in agricultural development, while Eshetu suggests strengthening managerial and technical capacity of forestry staff through adequate in-service training and technical guidelines. Nega advises investment in human resource development for irrigation technicians and irrigation agronomists. Also at the individual level, Gissila acknowledges that the improvement of knowledge in climate variability and downscaling of projection requires availability of trained human resources in climate change models. At the institutional level, he suggests that capacity building of the major stakeholder institutes is required to facilitate collaboration among the various agencies to be involved in improving agrometeorological services to farmers. Also at an institutional level, Dalle concludes that addressing transboundary issues requires building capacity among different ministries within East African countries to address issues related to transboundary resources.

Addressing research and knowledge gaps

Teklewold et al. specify a number of areas in which additional research can help with climate change adaptation. First, they recommend that inventories of community-based adaptation strategies be created and then tested for their impact on poverty and the potential for scaling up. Next, they recommend improved national and regional data collection, dissemination and analysis to do detailed climatic analyses to define vulnerability and formulate decision support. Finally, they suggest improving and expanding research to generate data and technologies appropriate to adaptation within the different agro-ecological zones of the country. Gissila also addresses the need for development of agrometeorological decision support tools for the various agro-ecological zones of Ethiopia. Tegegne calls attention to the need for detailed assessments of localized impacts to be able to identify appropriate options for livestock keepers to adapt to climate change, and Nega calls for more agricultural research on the use of new crop varieties that are tolerant to drought.

Increased investment and funding

Adapting to climate change within Ethiopia will require increased investment by both public and private sectors on research, agricultural extension, scaling up of new technologies, awareness campaigns and early warning systems. Teklewold et al. call for increased investments in both agricultural productivity and funding for adaptation programs, including accessing funds from international donors. Nega suggests increasing investment in

agricultural water management to improve crop productivity and ward off problems of water scarcity in the future. He also sees the need for more investments in irrigation, rainfed agriculture, water harvesting and efficient water saving technologies. In his paper on transboundary issues, Dalle suggests providing drought early warning systems and awareness campaigns, both of which would require increased funding.

Involvement of local communities

Tackling climate change adaptation will require strategies built from the bottom up in addition to policies and other approaches implemented from the top down. Many authors within these proceedings acknowledge that involving local communities and lower levels of government will be critical for success. The most fundamental recommendation is to improve awareness and understanding of local communities about the connection between climate change and crop production (Teklewold et al., Chapter 2). Similarly, Tegegne highlights that there is a strong need to support community-based adaptation projects with poor and vulnerable communities in rural and urban areas. Desta states that pastoralists can adapt to climate change successfully if given the right enabling environment, but of critical importance is Dalle's recommendation to promote peaceful ethnic coexistence, indigenous methods of resource sharing and conflict resolution in pastoral areas. The success of such measures and other policies, as stated by Abebe, hinges on communicating with and involving local communities.

To close the gender gap in agriculture, Oxfam recommends working with local communities to overcome taboos that limit women's participation in agricultural activities. A range of approaches needs to be tested, such as plays and trainings, to target both men and women. Tesema reports that indigenous knowledge is an invaluable resource to conserve agrobiodiversity, and Dale encourages empowerment of the Woreda as a component of creating an enabling environment for adoption of sustainable land management practices.

Enhanced agricultural extension services

Improving food security in the face of a changing climate in Ethiopia will require improved agricultural extension services to help farmers adapt. Teklewold et al. recommend investing in and improving such services, as does Oxfam, particularly for women farmers. Women-friendly and gender responsive agricultural extension systems are needed to help women

improve their productivity, which will go a long way in improving household food security. Extension services are recommended by Nega for promoting drought tolerant crop varieties, and Gissila discusses how to integrate agrometeorological advisory services into the extension system so that farmers can better plan for the coming seasons.

There are a variety of adaptation and mitigation strategies proposed by various authors throughout the papers. Agricultural extension services can help promote these practices and thereby enhance the adaptive capacity of Ethiopian farmers. It is important to consider the environmental sustainability of any strategies to ensure that achievement of short-term goals does not increase the country's vulnerability in the long term. Agriculture is both affected by and contributes to climate change, and there is a need to find ways of mitigating its contribution to global warming and minimizing the impacts of global warming on agriculture. Sustainable land management measures can increase the resilience of land users to climate shocks and allow the sequestration of carbon to help mitigate climate change.

The recommendations found in these 13 papers can lay a solid framework for the Ethiopian government to improve its climate change policies and enhance its research in critical sectors and regions. The groundwork has been laid through such documents as the Climate Resilient Green Economy mission statement and the Ethiopian Programme of Adaptation on Climate Change. Enhancing capacity in key sectors such as agrometeorological advisories and downscaling climate change models, improving agricultural extension services especially for women, increasing research in new crop varieties, and creating policies to allow mobility of pastoralists are all key areas which can help reduce the vulnerability of Ethiopian agriculture to climate change.



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