



CLIMATE CHANGE IMPACTS ON HOUSEHOLD FOOD SECURITY AND ITS ADAPTATION OPTIONS IN RURAL ETHIOPIA: A SYSTEMATIC REVIEW

Metadel Fekad¹

¹Department of Rural Development and Agricultural Extension, College of Dry land Agriculture and Natural Resources, Mekelle University, Mekelle, Ethiopia

Yihunie Bekalu²

²Ethiopian Environment and Forest research Institute, Addis Ababa, Ethiopia

Article DOI: <https://doi.org/10.36713/epra4142>

ABSTRACT

Food security is highly sensitive to climate risks in Ethiopia. More recent climate related events such as the 2016/2017 food security crises in the Horn of Africa specifically in Ethiopia have highlighted the impact of droughts and floods on food production, access to markets, and income from agricultural activities. However, assessing the ways in which livelihoods and specific vulnerabilities are linked to climate is a difficult task given the complex relationships between other environmental and socioeconomic factors in determining food security outcomes. The purpose of this review is to contribute to a quantitative and qualitative assessment of climate risk impacts (including climate variability, change, and extremes) on food security and livelihoods and adaptation options. The analytical method carried out for this review consists of two main components qualitative and quantitative approach and a dynamic analysis to evaluate the relationship between historic and current climatic variability and food security indicators, using long-term historical data; and a descriptive analysis to establish a baseline against which vulnerability to future risks can be assessed. The review reveals that Climate: In addition, some analysts suggest that there has been a shift in the timing of rainfall, leading to more erratic and unpredictable precipitation patterns.. Households depend heavily on markets and in-kind contributions during the agricultural lean seasons. If March-September precipitation continues to decline, food access could be affected in two inter-related ways. First, reduced crop production due to lower precipitation would force households to purchase more of their food. Second, climate-induced food price volatility could require households to spend more of their income on food. In addition, climate-related disasters limit physical access to markets. Climate impacts on livelihoods. The poorest farmers rely especially on food-based coping strategies and options such as reducing the quantity or quality of meals. Similarly, they rely on livestock sales or temporary labour migration. In recent years, however, there has been limited capacity of host areas to offer employment due to increasingly erratic rainfall which is reducing labour availability.

KEY WORDS: *climate change, food security, adaptation, systemic review*



INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) recognizes that developing countries are the most vulnerable to the adverse effects of climate change because they have fewer resources to adapt geo-physically, socially, technologically and financially (UNFCCC, 2007). The world's climate has always varied naturally. Climate trends are important in Ethiopia. The World Bank (2006) has linked changes in economic productivity to rainfall variability such that years with higher economic growth are associated with years with higher rainfall. Food security is among the most climate-sensitive sectors in the country; the National Adaptation Programme of Action (NAPA) prioritizes agriculture and food security as the most vulnerable sectors to the adverse effects of climate change and variability. Human actions are now imposing a relatively rapid change on the global climate.(4) This is occurring primarily as a result of increases in greenhouse gas (GHG) emissions from power generation, agriculture, mining and transport, and from reductions in the extent and capacity of nature's carbon 'sinks' (especially via deforestation). Climate scientists agree that human-induced climate change accounts for most of the warming, since mid-twentieth century. (4)

There is also evidence that the rates of change (e.g. in emissions, sea-ice loss and sea-level rise) are accelerating, despite growing governmental and public awareness of this global environmental problem.

The global climate has warmed by 0.8°C since early in the twentieth century. As a result, 'increases in the frequency and intensity of various extreme events', such as tropical cyclones (including hurricanes and typhoons), floods, droughts and heavy precipitation events have occurred. Due the inertia in the system, the full influence from current CO₂ levels has yet to fully unfold, however this rise in extreme events across the globe provides indication of the trend. The "business as usual" (BAU) pathway of current emissions patterns produces a mid-range warming estimate of 4.5° C (range 3° C – 7° C) by 2100.(5)

Even if global CO₂ emissions stopped today, the oceans' thermal inertia will continue to drive the world's temperature higher by 0.3° C -0.8° C (by 2100), possibly higher, and sea-level rise continue to rise about 10cm/century from many centuries.(6)

Complete cessation of emissions is clearly impossible to achieve and so represents an extreme

lower boundary to climate change over the next few centuries.

Even with relatively small temperature increases, changes in some types of extreme events will amplify as higher average temperature leads to a disproportionately large increase in the number of extreme climatic events.(7)

While mitigation is an urgent necessity to prevent these worst case scenarios, adaptation is essential to minimize the adverse health outcomes from current and future warming.

The relationship between climate, and therefore climate change, and food security is complex and predominantly non-linear. Climate change, itself, has many dimensions and various environmental and social impacts that then, in turn, affect food security. There are multiple drivers of food insecurity in Ethiopia – including drought risk, environmental degradation, demographic pressure, rural-urban migration, and conflict. In the absence of adaptation measures, climate variability and change act as risk multipliers, exacerbating the conditions which affect food security trends. Rainfall patterns are extremely complex in Ethiopia. Recent trends show that rainfall in the period March-September has decreased significantly since the 1990s across most of the country (particularly in northern, south-central and south-eastern parts of the country). There is also high inter-seasonal variability with belg rains (February-May) being more variable than meher rains (June-October). The analysis presented here provides a foundation to better understand the links between climate risk and food security. The analysis of the review has the following three main objectives.

Objective of the review

- ✓ To identify spatial and temporal relationships between food security and climate;
- ✓ To establish a vulnerability baseline to assess the factors that contributes to household vulnerability to climate risks.
- ✓ To identify a set of key policy priorities to build adaptive capacity and reduce climate-related food insecurity in the most vulnerable communities.
- ✓ To identify the major climate change adaptation options adopted by smallholders
- ✓ To investigate the climate change scenarios on agricultural production



Key terms and concepts

Climate: This is typically described by the summary statistics of temperature, precipitation, soil moisture and sea surface temperature of a particular region, averaged over a set time-scale, usually 30 years.

Climate variability: This is the variation around the average climate, ranging from daily/weekly variability to seasonal and intra-decadal variations. Beyond that time scale, variation merges with 'change'.

Climate change: Climate change is identified by changes over an extended period in the average and/or variability of properties such as temperature and precipitation. This report also considers elevated atmospheric carbon dioxide (CO₂) concentrations, which are a driver of climate change. Human activities have resulted in large changes in Earth's climate over the last few centuries (Stocker et al. 2013).

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences.

Carbon sequestration: The uptake (i.e., the addition of a substance of concern to a reservoir) of carbon-containing substances, in particular carbon dioxide (CO₂), in terrestrial or marine reservoirs. Biological sequestration includes direct removal of CO₂ from the atmosphere through land-use change, afforestation, reforestation, revegetation, carbon storage in landfills, and practices that enhance soil carbon in agriculture (e.g., cropland management, grazing land management).

Climate change is usually described statistically by changes in the mean and/or the variability of atmospheric properties such as temperature and precipitation.

- **Natural climate change** is caused by internal climate system processes, such as cyclical changes in atmospheric and ocean circulation, or natural forces external to the climate system, such as volcanic eruptions or a decrease or increase in solar energy entering the atmosphere.

- **Anthropogenic climate change** is caused by human activities, such as land-use change or industrial processes that result in GHG emissions that change the composition of the atmosphere, and is in addition to natural climate variability observed over comparable time periods.
- **Climate change impact assessment**—the practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of climate change on natural and human systems.

Climate model: A numerical representation of the climate system based on the physical, chemical, and biological properties of its components and their interactions and feedback processes, and accounting for some of its known properties.

Climate prediction: A climate prediction or climate forecast is the result of an attempt to produce (starting from a particular state of the climate system) an estimate of the actual evolution of the climate in the future, for example, at seasonal, inter-annual, or decadal time scales. Because the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

Climate projection: The simulated response of the climate system to a scenario of future emissions or concentrations of GHG and aerosols generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate. A climate change scenario is the difference between a climate scenario and the current climate.

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales



beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcings (external variability).

Crop yield: The measurement of the amount of cereal, grain, or legume produced per unit area, normally measured in metric tons per hectare. Yield multiplied by area harvested equals total agricultural production for a crop in a region.

Demography: The statistical study of human population size, trends, density, distribution, and other vital data.

Distributing: Transporting unprocessed and processed food to a market, between markets, and from a market to communities for retail.

Domestic supply: The amount available for food consumption once other uses (e.g., animal feed, biofuels) and food exported and either put in or taken out of stock are calculated at the national level. When divided by the total population, it estimates the per-capita food available for consumption.

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought) and during the runoff and percolation season primarily affects water supplies (hydrological drought). Soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A mega drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2015).

Extensification: Using more land to grow more food, typically using traditional management strategies, as opposed to sustainable intensification on land already in use through improved farm management.

Extreme event: An event that causes large fluctuations in the behavior of an element of the food

system, such as a large reduction in agricultural yield or abrupt changes in the price of oil. By definition, the characteristics of what is called an extreme event may vary from place to place.

Famine: An extreme food shortage during which at least 20% of households in an area have a limited ability to cope, the acute malnutrition rate exceeds 30%, and the crude death rate exceeds either 2 per 10,000 per day or the under-5 mortality rate exceeds 4 per 10,000 per day.

Food sovereignty: The right of countries and peoples to define agricultural, pastoral, fishery, and food policies that are ecologically, socially, economically, and culturally appropriate for them.

Food supply chain: A network of food-related business enterprises through which food products move from production through consumption, including preproduction and post consumption activities.

Food system: Encompasses activities whose ultimate goal is individual food consumption: that is, producing, processing, packaging, distributing, and transporting, refrigerating, retailing, preparing, and consuming food.

Food value chains: Food value chains are distinguished from traditional food supply chains by the combination of how they operate as strategic partnerships (business relationships) and how they differentiate their products (by focusing on food quality and functionality, and environmental and social attributes).

Intensification: Intensification in conventional agriculture is understood primarily as using a higher input of nutrient elements and of pesticides per land unit. It also means more energy (direct for machinery and indirect for inputs).

Mitigation: A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Resilience: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Risk: The potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the consequences if these events occur. This report assesses climate-related risks.



Risk assessment: The qualitative and/or quantitative scientific estimation of risks.

Risk management: The plans, actions, or policies implemented to reduce the likelihood and/or consequences of a given risk.

Weather: The state of the atmosphere, mainly with respect to its effects upon life and human activities. As distinguished from climate, weather consists of the short-term (minutes to months) variations of the atmosphere. Popularly, weather is thought of in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, and wind.

FINDINGS

The review analysis and highlights the following trends:

Climate: Recent rainfall data show trends of overall declines in rainfall between March and September from 1980 to the present. These declines have been most marked in belt-dependent areas leading to more intense and frequent droughts across different the country. In addition, some analysts suggest that there has been a shift in the timing of rainfall, leading to more erratic and unpredictable precipitation patterns.

Climate impacts on food production: With a predominantly rain-fed agricultural system, rainfall is one of the main climatic determinants of food production in Ethiopia. Wetter years are generally associated with higher food production; conversely dry years are linked to lower production.

Climate impacts on food access: Access to markets is critical for food security in Ethiopia: even in the most productive areas, poorer farmers purchase some of their food. This is especially the case in the pastoral areas, as well as in agricultural areas where rainfall has become increasingly erratic. Households depend heavily on markets and in-kind contributions during the agricultural lean seasons. If March-September precipitation continues to decline, food access could be affected in two inter-related ways. First, reduced crop production due to lower precipitation would force households to purchase more of their food. Second, climate-induced food price volatility could require households to spend more of their income on food. In addition, climate-related disasters limit physical access to markets.

Climate impacts on livelihoods: Across most of Ethiopia, households report lack of erratic rainfall as the main risk contributing to their food insecurity and overall vulnerability. The poorest farmers rely especially on food-based coping strategies such as reducing the quantity or quality of meals. Similarly,

they rely on livestock sales – often selling their last productive female or temporary labour migration. In recent years, however, there has been limited capacity of host areas to offer employment due to increasingly erratic rainfall which is reducing labour availability.

Climate change and Food security

Climate change is very likely to affect global, regional, and local food security by disrupting food availability, decreasing access to food, and making utilization more difficult. Climate change is projected to result in more frequent disruption of food production in many regions and in increased overall food prices. Climate risks to food security are greatest for poor populations and in tropical regions. The potential of climate change to affect national food security is important for food producers and consumers in Ethiopia.

Climate change risks extend beyond agricultural production to other elements of global food systems that are critical for food security, including the processing, storage, transportation, and consumption of food. Production is affected by temperature increases; changes in the amount, timing, and intensity of precipitation; and reduced availability of water in dry areas. Processing, packaging, and storage are very likely to be affected by temperature increases that could increase costs and spoilage. Temperature increases could also make utilization more difficult by increasing food- safety risks. Sea-level rise and precipitation changes alter river and lake levels, and extreme heat can impede waterborne, railway, and road transportation.

Constraints in one component of food security may sometimes be compensated through another for-example; food insecurity may be avoided when production decreases (availability) are substituted with food acquired through purchase (access).

Alternatively, constrictions at one point within the food system may be so severe, or have no feasible alternative possibilities within a local context, that food security may be compromised. As a consequence of these interactions and dependencies, a systems-based approach is needed to understand the implications of climate change on food security.

Climate risks to food security increase as the magnitude and rate of climate change increase. Higher emissions and concentrations of greenhouse gases are much more likely to have damaging effects than lower emissions and concentrations.

Worst-case projections based on high greenhouse-gas (GHG) concentrations (~850 ppm),



high population growth, and low economic growth imply that the number of people at risk of undernourishment would increase by as much as 175 million above today's level by 2080. The same socioeconomic conditions with GHG concentrations of about 550 ppm result in up to 60 million additional people at risk, while concentrations of about 350 ppm less than today's level do not increase risk. Scenarios with lower population growth and more robust economic growth result in large reductions in the number of food insecure people compared to today, even when climate change is included, but higher emissions still result in more food insecurity than lower emissions.

Effective adaptation can reduce food-system vulnerability to climate change and reduce detrimental climate-change effects on food security, but socioeconomic conditions can impede the adoption of technically feasible adaptation options.

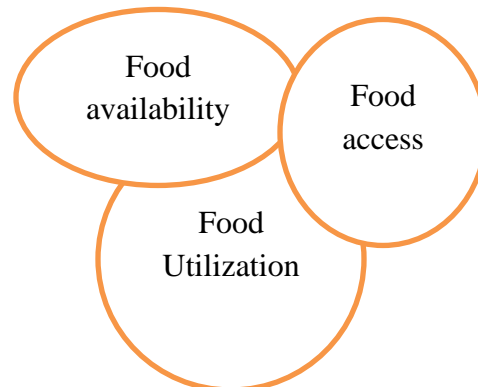
The agricultural sector has a strong record of adapting to changing conditions. There are still many opportunities to bring more advanced methods to low-yield agricultural regions, but water and nutrient availability may be limiting in some areas, as is the ability to finance expensive technologies. Other promising adaptations include innovative packaging and expanded cold storage that lengthen shelf life, improvement and expansion of transportation infrastructure to move food more rapidly to markets, and changes in cooking methods, diets, and purchasing practices. The complexity of the food system within the context of climate change allows for the identification of multiple food-security intervention points, which are relevant to decision makers at every level.

The future need for, and cost of, adaptation is lower under lower emissions scenarios. Trade decisions could help to avoid large-scale price shocks and maintain food availability in the face of regional production difficulties such as drought. Improved transportation systems help to reduce food waste and enable participation in agricultural markets. Public- and private-sector investments in agricultural research and development, coupled with rapid deployment of new techniques, can help to ensure continued innovation in the agricultural sector. Refined storage and packaging techniques and materials could keep foods safer for longer and allow for longer-term food storage where refrigeration is absent and food availability is transient.

Accurately projecting climate-change risks to food security requires consideration of other large

scale changes. Ecosystem and land degradation, technological development, population growth, and economic growth affect climate risks and food security outcomes. Population growth, which is projected to add another 2 billion people to Earth's population by 2050, increases the magnitude of the risk, particularly when coupled with economic growth that leads to changes in the types of foods demanded by consumers. Sustained economic growth can help to reduce vulnerability if it reduces the number of poor people and if income growth exceeds increases in food costs in vulnerable populations. Analyses based on scenarios of sustained economic growth and moderate population growth without climate change suggest that the number of food-insecure people could be reduced by 50% or more by 2040, with further reductions over the rest of the century. Such analyses should not be misinterpreted as projections, since climate change is already occurring, but they clearly indicate that socioeconomic factors have large effects on food insecurity.

Food Availability: Production; Distribution; Exchange



(Modified from: FAO, 2002)

Food Access: Affordability; Allocation; Preference

Food utilization: Nutritional value; Social value; Food safety

Emission trends

The primary contributor to global climate change is carbon dioxide (CO₂), which is released by the burning of fossil fuels as well as by land-use change, particularly deforestation. Carbon dioxide emissions from fossil fuel use rose to 26.4 billion metric tons per year in 2000-2005, with the contribution of carbon dioxide emissions from land-use change (mainly deforestation).



Based on these trends, the following recommendations to manage climate risks are proposed:

Mainstreaming climate risk management into development and food security strategies

Integrating climate risk management structures into broader development pathways offers a cost effective manner to address multiple development challenges, while accounting for the emerging risks posed by climate variability and change. Disaster risk reduction structure, social protection and safety nets offer critical platforms and vehicles for investing in risk management for the most vulnerable and should become a policy priority. Scaling up risk management is critical in view of a changing risk environment characterised by increasing risks as well as larger numbers of people exposed to these risks. Successful scaling up should be implemented at the community level, as well as at the national, regional and global levels by adapting successful experiences and best practices in resilience building.

Focus on the most vulnerable

All rural livelihood systems in Ethiopia are highly sensitive to climate given the dependence of cropping, pastoral and agro-pastoral communities on rainfall. Recent climate trends show that rainfall is decreasing in the south-central, southeastern, and northern parts of the country, while the western parts of the country have been receiving more rainfall potentially increasing the magnitude of droughts and floods. Strategies for livelihood and income diversification are critical to ensuring resilience against more intense climate-related risks. For example, migration (both seasonal and permanent) has become an important source of household income for at-risk populations. Landscape transformation through land rehabilitation can also be a cost-effective solution to manage climate risks, by contributing to both drought and flood risk management.

This analysis highlights that all rural livelihood systems in Ethiopia are highly sensitive to climate given the dependence of cropping, pastoral and agro-pastoral communities on rainfall. Belg-dependent areas are particularly vulnerable, especially given the increasing variability in belg rainfall over the last few years. Recent climate trends show that rainfall is decreasing in the south-central, southeastern, and northern parts of the country, while

the western parts of the country have been receiving more rainfall – and climate projections are consistent with these trends. This in turn suggests that the magnitude of droughts and floods may increase under climate change. In this context, strategies for livelihood and income diversification are critical to ensuring resilience against more intense climate-related risks. For example, migration (both seasonal and permanent) has become an important source of household income for at-risk populations. Increasing voluntary labour mobility is a low-cost, low-regret approach that contributes to the adaptive capacity of communities through networks that are used to exchange goods, services and information while also giving at-risk populations the opportunity to adapt based on their needs. Support to additional income sources, such as wage labour, skilled non-farm activities and forest management can lead to improved livelihoods.

Landscape management could also contribute to effective flood risk management through the expansion and refurbishment of irrigation and water storage infrastructure, capacity building for water-efficient cropping practices, and adoption of flood-resilient crop varieties. Manage uncertainties associated with climate change

One of the key characteristics in terms of climate risk in Ethiopia is that both droughts and floods can occur in the same growing season, with potentially devastating impacts on crop and livestock production. Strategies to address climate risk should focus on developing capacities to better analyses and anticipate risks. For instance, the introduction of early warning systems and contingency plans can support climate risk management and food security strategies. Investments should also be made in strengthening analytical tools such as early warning systems, and risk assessment and monitoring systems to enhance detailed and up-to-date risk information.

Manage uncertainties associated with climate change

Both droughts and floods can occur in the same growing season, with potentially devastating impacts on crop and livestock production. Strategies to address climate risk should focus on developing capacities to better analyse and anticipate risks. The introduction of early warning systems and contingency plans can support climate risk management and food security strategies.



Role of agriculture in climate change problem

Contribution of agriculture to climate change is often overlooked;

IPCC estimated that 31% of total emission of GHGs in 2004 came from agriculture and forestry;

Hence, mitigation efforts must also address contribution of agriculture to the climate change problem

Rainfall variability Vs. GDP in Ethiopia

Source: World Bank, 2006. A Country Water Resources Assistance Strategy for Ethiopia

Key findings in Ethiopia

- Extreme hydrological variability is echoed in its economic performance;
- Vast majority (80%) of Ethiopia's population subsists on rainfed agriculture;
- People's welfare and economic productivity are linked to the volatile rains; and
- There is a strong correlation between rainfall and overall GDP.

There are multiple drivers of food insecurity in Ethiopia – including drought risk, environmental degradation, demographic pressure, rural-urban migration, and conflict. In the absence of adaptation measures, climate variability and change act as risk multipliers, exacerbating the conditions which affect food security trends. Rainfall patterns are extremely complex in Ethiopia. Recent trends show that rainfall in the period March-September has decreased significantly since the 1990s across most of the country (particularly in northern, south-central and south-eastern parts of the country). There is also high inter-seasonal variability with belg rains (February-May) being more variable than meher rains (June-October).

RISKS, OPPORTUNITIES AND ADAPTATION OPTIONS

Interactions between climate change and land use change present a number of risks for biodiversity conservation, but also several opportunities. The complex nature of interactions between global change drivers means that we may never have accurate predictive models for biodiversity impacts. For example, the effects of increased drought under climate change may be moderated by local land use, but climate change also affects species phenology which will influence their sensitivity depending on when in the year a drought occurs. In addition to interaction chain and modification effects between drivers, the effects on individual species may cascade

through communities causing unanticipated effects. These problems are in addition to the fact that there are clear difficulties in obtaining reliable projections of land use and climate change on which to base our projections for biodiversity. Therefore, predicting combined effects of multiple drivers on biodiversity is particularly challenging. From a more positive perspective, interactions between land use change and climate change present opportunities to lessen climate change impacts by adapting land use and management. Adaptation to climate change has become a major priority for conservation, it can be defined as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities.

A wide range of high level principles for adaptation have been identified. Climate change adaptation can be viewed as a spectrum of responses from building resilience of existing ecosystems, populations, and communities to accommodating inevitable change, to promoting transformational change.



A. CO2 fertilization effects

Impact on food system assets	Impact on food system activities	Impact on food security outcomes	Impact on other human well-being outcomes	Possible adaptive responses
<p>Production assets:</p> <ul style="list-style-type: none"> Increase in availability of atmospheric carbon dioxide for plant growth 	<p>Producing food:</p> <ul style="list-style-type: none"> More luxuriant biomass Higher yields of food and cash crops, mainly in temperate regions 	<p>Food availability (production, distribution, exchange):</p> <ul style="list-style-type: none"> Increased food production in major exporting countries would contribute to global food supply but diversion of land from food to more economically attractive cash crops could negate this benefit <p>Food accessibility (allocation, affordability, preference):</p> <ul style="list-style-type: none"> Increases in food production would limit price increases on world markets, but diversion of productive assets to other cash crops could cause food prices to rise 	<p>Livelihoods:</p> <ul style="list-style-type: none"> Increased income from improved food and cash crop performance would benefit commercial farmers in developed countries but not in developing countries 	<p>Policies and regulations:</p> <ul style="list-style-type: none"> Avoidance of subsidies or other monetary or non-monetary incentives for diversion of food production assets to other uses

B. Increase in global mean temperatures

Impact on food system assets	Impact on food system activities	Impact on food security outcomes	Impact on other human well-being outcomes	Possible adaptive responses
<p>Production assets:</p> <ul style="list-style-type: none"> Trend changes in suitability of land for crop and 	<p>Producing food:</p> <ul style="list-style-type: none"> Immediate crop and livestock losses due to heat 	<p>Food availability (production, distribution, exchange):</p>	<p>Livelihoods:</p> <ul style="list-style-type: none"> Trend changes in vectors and natural habitats of 	<p>Policies and regulations</p> <ul style="list-style-type: none"> Greater reliance on weather-related



<p>livestock production</p> <ul style="list-style-type: none"> ▪ Gradual loss of biodiversity ▪ Trend changes in vectors and natural habitats of plant and animal pests and diseases <p>Storage, transport and marketing infrastructure:</p> <ul style="list-style-type: none"> ▪ Strain on electricity grids, air conditioning and cold storage capacity 	<p>and water stress</p> <ul style="list-style-type: none"> ☒ Lower yields from dairy animals ☒ Reduced labour productivity due to heat stress ☒ Trend impacts uncertain, conditional on location, availability of water and adoption of new cropping patterns by farmers <p>Storing and processing of food:</p> <ul style="list-style-type: none"> ☒ Upgrade in cooling and storage facilities required to maintain food quality at higher temperatures ☒ Increasing energy requirements for cooling <p>Consuming food:</p> <ul style="list-style-type: none"> ☒ Higher intake of liquids ☒ Lower intake of cooked food ☒ Perishable products have shorter shelf life ☒ More need for refrigeration ☒ Heat stress may negatively affect people's ability to access food (no energy to shop or do productive work) 	<ul style="list-style-type: none"> ▪ Reduced production of food crops and livestock products in affected areas ▪ Local losses could have temporary effect on local markets, ▪ Reduction in global supplies likely to cause market prices to rise <p>Food accessibility (allocation, affordability, preference):</p> <ul style="list-style-type: none"> ▪ Impacts on incomes, prices and affordability uncertain ▪ Changes in preference uncertain <p>Food utilization (nutritional value, social value, food safety):</p> <ul style="list-style-type: none"> ▪ Risk of dehydration ▪ Risk of ill health from eating food that is spoiled ▪ Ability of body to process food reduced due to heat stress or diseases <p>Food system stability:</p> <ul style="list-style-type: none"> ▪ Higher cost for storing grain and perishable products 	<p>pests and diseases that affect human health and productivity</p> <p>Social values and behaviours:</p> <ul style="list-style-type: none"> ▪ Acceptance of a greater degree of risk and uncertainty as a natural condition of life <p>National and global economies:</p> <ul style="list-style-type: none"> ▪ Reorientation of public and private sector investments towards mitigating and adapting to climate change 	<p>insurance</p> <ul style="list-style-type: none"> ▪ Development of risk management frameworks <p>Farming, forestry and fishery practices</p> <ul style="list-style-type: none"> ▪ Trend changes in cropping patterns ▪ Development and dissemination of more heat- tolerant varieties and species <p>Food processing, distribution and marketing practices</p> <ul style="list-style-type: none"> ▪ Greater use of alternative fuels for generating electricity <p>Food preparation practices</p> <ul style="list-style-type: none"> ▪ Greater use of alternative fuels for home cooking
---	---	--	---	--



C.1. Gradual changes in precipitation (increase in the frequency, duration and intensity of dry spells and droughts)				
Impact on food system assets	Impact on food system activities	Impact on food security outcomes	Impact on other human well-being outcomes	Possible adaptive responses
<p>Production assets</p> <ul style="list-style-type: none"> Loss of perennial crops and vegetative cover for grazing and fuel wood due to water stress and increasing fire hazard Loss of livestock due to water stress and lack of feed Loss of productive assets due to hardship sales Loss of buildings, equipment and vehicles and other productive assets due to fire Changes in rates of soil moisture retention and aquifer recharge Trend changes in suitability of land for crop and livestock production Gradual loss of biodiversity Trend changes in vectors and natural habitats of plant and animal pests and diseases 	<p>Producing food:</p> <ul style="list-style-type: none"> Immediate crop and livestock losses due to water stress Trend declines in yields Change in irrigation requirements <p>Storing/processing of food:</p> <ul style="list-style-type: none"> Less need for chemicals to preserve stored grain Scarcity of water for food processing <p>Distributing food:</p> <ul style="list-style-type: none"> Easier movement of vehicles on dry land <p>Consuming food:</p> <ul style="list-style-type: none"> May not be possible to continue growing preferred foods May be necessary to purchase a larger proportion of foods consumed Diet may become less 	<p>Food availability (production, distribution, exchange):</p> <ul style="list-style-type: none"> Declines in production Wild foods less available Pressure on grain reserves Decrease in food exports / increase in food imports Increased need for food aid <p>Food accessibility (allocation, affordability, preference):</p> <ul style="list-style-type: none"> Local increase in food prices in drought-affected areas Loss of farm income and non- farm employment Preferred foods not available or too costly <p>Food utilization:</p> <ul style="list-style-type: none"> Risk of dehydration Ability of body to process food reduced due to diseases 	<p>Livelihoods:</p> <ul style="list-style-type: none"> Decline in expenditure for other basic needs, e.g., clothing, shelter, health, education Trend changes in vectors and natural habitats of pests and diseases that affect human health and productivity <p>Social values and behaviours:</p> <ul style="list-style-type: none"> Food scarcity strains ability to meet reciprocal food- sharing obligations <p>National and global economies:</p> <ul style="list-style-type: none"> Strain on national budgets and aid resources due to increased need for food safety nets 	<p>Policies and regulations:</p> <ul style="list-style-type: none"> Greater reliance on weather- related insurance Development of risk management frameworks <p>Infrastructure investments</p> <ul style="list-style-type: none"> New investment in irrigation for intensive agriculture where water resources permit <p>Farming, forestry and fishery practices</p> <ul style="list-style-type: none"> Trend changes in cropping patterns Development and dissemination of more drought-tolerant varieties and species Use of moisture-retaining land management practices Use of recycled wastewater for irrigation



<p>Food preparation assets</p> <ul style="list-style-type: none"> ▪ Lack of water for cooking ▪ Lack of vegetation for fuel 	<p>varied and / or less nutritious</p>	<ul style="list-style-type: none"> ☒ Dietary adjustments with different nutritional content <p>Food system stability:</p> <ul style="list-style-type: none"> ☒ Greater instability of food supply, food prices and agriculturally-based incomes 		<p>Food processing practices:</p> <ul style="list-style-type: none"> ▪ Use of recycled wastewater ▪ Use of dry processing and packaging methods <p>Food preparation practices</p> <ul style="list-style-type: none"> ▪ Use of dry cooking methods
--	--	--	--	--

Source: FAO/IDWG on Climate Change. Table produced for this report



Responding to climate change: Building resilience and reducing vulnerability

The integration of climate change adaptation and mitigation into an overall development agenda is paramount to addressing the impact of climate change on food security. The need for stakeholders' engagement in employing a holistic approach in addressing effect of climate change is critical for ensuring food security. It is necessary to strengthen the resilience of rural people and to help them cope with this additional threat to food security. Particularly in the agriculture sector, climate change adaptation can go hand-in-hand with mitigation.

Strengthening resilience involves a conscious effort in adopting practices that protect vulnerable people for diversification of income sources, ensuring the existence of existing livelihood systems. Mitigation involves controlling greenhouse gases to stabilize climate change at an acceptable limit. Adaptation on the other hand refers to adjustments to the impact of climate change given existing levels of greenhouse gasses in the atmosphere.

Addressing vulnerability should be a household approach rather than a general approach because the ability to cope and adapt to climate change impact varies from one household to another and also among individuals.

Long-term policy responses require accurate information about the economic impacts of future climatic conditions. Despite recent advances in analysing the economic effects of global warming, information about climate change and food security in developing countries remains extremely limited. Specific details are lacking about the location, timing, magnitude, and probability with which food security issues might arise (Darwin 2001).

Future food security depends on investments decisions made today for tackling climate change, conserving water and energy resources, developing and adopting new seeds, renewed investments in irrigation, shoring up domestic food production, reforming international trade, and diversification of food production away from farming. Future food security requires governments and the public to deal forcefully with the issues critical in food production and food security, including population growth, widespread poverty and income disparity, climate change, water scarcity, land degradation and energy and food price inflation. Addressing these interlocking issues simultaneously is inevitable to prevent famine in poor nations (Hanjra and Qureshi 2010).

CONCLUSION AND RECOMMENDATION

This review focuses on the anticipated effects of climate change on food security and its adaption options. Climate change and land use change interact to impact biodiversity through a wide range of mechanisms. Understanding these interactions will be necessary to more reliably project changes in biodiversity under different land use and climate scenarios and to manage habitats appropriately. There are also opportunities to reduce the negative impact of climate change on biodiversity through adaptation strategies and relatively simple actions such as increasing habitat quality and extent can simultaneously address multiple drivers. However, land use decisions can also have negative impacts on the 'adaptive capacity' of populations.

Land use is driven by socioeconomic and climatic factors, potentially with complex feedbacks; but if we cannot suitably address the negative impacts of land use change, then we close off our options for dealing with climate change. With a growing recognition of the existence of interactions between global change drivers, conservation strategies and biodiversity projections that only address a single driver are inadequate. Future research needs to understand and quantify the major mechanisms by which global change drivers interact, in order to minimize risks and increase opportunities for the conservation of biodiversity. There are substantial uncertainties regarding the degree to which environmental conditions will change; the response of plants, animals, and farm labor; and potential adaptations to these changes. Although these uncertainties render predicting exact changes in future food production difficult, the evidence base strongly implies the need to prepare for a wide range of possible outcomes.

Furthermore, our review of the evidence indicates that environmental changes are generally tilted against environments that are already hot and have the least resources for adaptation. Our global and local food systems need urgent action to reduce GHG emissions in ways that enable resilience and sustainability.

Though an extensive body of research explores how we can mitigate and adapt to climate change (CC) in agriculture, substantially less work has focused across the food system to explore opportunities for climate mitigation and adaptation more comprehensively. Here, we highlight some of



the key strategies across the food system to mitigate emissions, and their applicability in varying country contexts. We have illustrated ways in which certain mitigation options in specific food system components could have profound impacts on other areas and also potentially offer adaptation co-benefits. However, the majority of existing peer-reviewed literature does not examine CC in food systems through this lens.

Ethiopia is also frequently identified as a country that is highly vulnerable to climate variability and change. The potential adverse effects of climate change on Ethiopia's agricultural sector are a major concern, particularly given the country's dependence on agricultural production, which is sensitive to climate change and variability.

Thus, future systems-level research is critical to assess connections to other sustainable development goals and ensure that mitigation of food system emissions does not have untold impacts in other sectors. Conducting this work in low- and middle-income countries is especially important as the policies and investments they put into place today will have a profound impact on their food systems, including its mitigation and adaptation capacity.

Several important policy implications can be drawn from this analysis. Feasible interventions to reduce vulnerability and ameliorate the impact of climate change revolve around promoting small-scale irrigation and crop diversification that would later or sooner help to increase food security. In line with this, it is, therefore, imperative to ensure access to alternative sources of income through non-farm and off-farm activities, improving infrastructure, and increase vulnerable farmers' asset base thereby increase their adaptive capacity to withstand the vagaries of the climate variability risk.

As often stated in climate change theory, vulnerability is a function of three contributing factors via adaptive capacity, sensitivity, and exposure. Higher adaptive capacity, lower exposure, and lower sensitivity reduce farmers' vulnerability to climate change impacts. In practice, although current adaptation options used by farmers helped reduce vulnerability through reducing sensitivity and enhancing adaptive capacity, determinants of adaptation options to climate change and variability remains an important concern. Future research needs to investigate factors constrains or facilitate the adoption of adaptation options to fully realize the benefit of adaptation options.

The proposals for a future international response to climate change are intended as illustrations of different impulses in the climate negotiations, not as the latest or most "realistic" examples of climate policy. The overview of the proposals demonstrates that fairness concerns figure prominently in a number of them. In addition, equity principles are also present in the policy evaluation criteria that are commonly put forward – for instance, in the concern that a future agreement should be responsive to the poverty eradication, food insecurity alleviation and economic development objectives of developing countries and that proposal should be capable of taking country-specific circumstances into account. That some of the approaches reviewed contain an explicit engagement with equity concerns is fitting and timely. With steadily rising GHG concentrations, the tradeoffs, national interests, and equity dimensions are ratcheted up. The longer the delay, the less time there is to begin taking sensible, low-cost options in the near-term, while integrating the need to move a low-carbon future into public awareness, public policy, and private investment decisions.

On the policy side, a successful future framework would ensure environmental effectiveness in line with a broadly defined and widely supported goal and, at the same time, would satisfy cost concerns. This would entail the engagement of developing countries in the joint effort to slow, and then reduce, global emissions, adaptation and resilience options and agriculture should mechanized and integrated to improve production and productivity for food security realization.

REFERENCES

1. ACF, IDS and Tearfund [Action Contre la Faim, Institute of Development Studies] (2009). *Changing Climate, Changing Lives*. London: ACF, IDS and Tearfund. *Agroecology-Based Analysis in the Muger Sub-Basin of the Upper Blue-Nile Basin of*
2. Amare, A. and Anyamba, A., Tucker, C.J., Mahoney, R. (2002). *From El Niño to La Niña: Vegetation Response*
3. Bewket, W. and Alemu, D. (2011). *Farmers' perceptions of climate change and its agricultural impacts in the Abay and Baro-Akobo River Basins, Ethiopia*. *Ethiopian Journal of Development Research*.
4. *Climate Change Global Food Security and the U.S. Food System Report*, (2015). U.S. Global Change Research Program climate change. *Food Policy no. 35:365–377*.



5. *Climate risk and food security in Ethiopia: Analysis of climate impacts on food security and livelihoods UNFCCC. Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. Bonn. 2007. Accessed: 6th May 2009. <http://unfccc.int/resource/docs/publications/impacts.pdf>.*
6. Cochrane, L. (2011). *Food Security or Food Sovereignty: The Case of Land Grabs. Online at: <http://sites.tufts.edu/jha/archives/1241>*
7. CSA (2011). *Ethiopia Demographic and Health Survey (EDHS), Preliminary Report. Addis Ababa: CSA.*
8. CSA (2012). *Agricultural Sample Survey. Addis Ababa: CSA.*
9. CSA [Central Statistical Agency] (2010). *Ethiopia: Statistical Abstract. Addis Ababa: CSA.*
10. Del Ninno, C., Dorosh, P.A. and Smith, L.C. (2003). *Public policy, markets and household coping strategies in Bangladesh: Avoiding a food security crisis following the 1998 floods. World Development 31(7): 1221–1238.*
11. DRMFSS [Disaster Risk Management and Food Security Sector of the Ministry of Agriculture] (2012). *Wereda Disaster Risk Profiles. Addis Ababa: DRMFSS.*
12. EM-DAT [The International Disaster Database] (2011). *The International Disaster Database.*
13. Eshetu, Z. and Loader, N.J. (2011). *Recent summer precipitation trends in the Greater Horn of Africa and the emerging role of Indian Ocean sea surface temperatures. Climate Dynamics. doi:10.1007/s00382-011-1222-y. Ethiopia. American Journal of Climate Change, 6, 668-693.*
14. *Ethiopia. Meteorology and Atmospheric Physics. 89: 153-180.*
15. FAO/ WFP (2012). *Crop and Food Security Assessment Mission to Ethiopia. Rome/Addis*
16. FAO/WFP [Food and Agriculture Organization and World Food Programme] (2010). *State of Food Insecurity in the World. Rome: FAO/WFP.*
17. FAOSTAT (2012). *Crop production statistics. Online at: www.fao.org/faostat*
18. FEWS NET (2012a). *Seasonal hunger. Washington, D.C.: FEWS NET. FEWS NET (2012b) Market flow analysis of Ethiopia. Washington D.C.: FEWS NET.*
19. FEWS NET [Food security Early Warning Systems Network] (2003). *Estimating meher crop production using rainfall in the 'long cycle' region of Ethiopia. Washington D.C.: USAID/FEWS NET.*
20. Fransen, S. and Kuschminder, K. (2009). *Migration in Ethiopia: History, Current Trends and Future Prospects Paper Series: Migration and Development Country Profiles. Maastricht Graduate School of Governance. Maastricht University*
21. Fuentes, R., and Seck, P. (2007). *The short-term and long-term human development effects of climate-related shocks: Some empirical evidence. New York: UNDP.*
22. Funk, C., Michaelsen, J. and Marshall, M. (2011). *Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel, in Wardlow, B.D., Anderson,*
23. *Hanjra, M. A., and M. E. Qureshi. 2010. Global water crisis and future food security in an era of <http://esa.un.org/unpd/wpp/index.htm>*
24. *<https://doi.org/10.4236/ajcc.2017.64034>*
25. IPCC (2007). *Summary for Policymakers. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and CEH, Eds., Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 7-22.*
26. *Jury, M.R. (2010). Ethiopian decadal climate variability. Theoretical and Applied Climatology. 101: 29-40.*
27. *Korecha, D. and Barnston, A.G. (2007). Predictability of June- September Rainfall in Ethiopia. Monthly Weather Review. 135: 628-650.*
28. *LandScan (2011). Land Scan Population Density Data. Online at: http://www.ornl.gov/sci/landscan/landscan_data_avail.shtml LEAP [Livelihoods, Early Assessment and*
29. *Lobell, D.B., Field, C.B. (2007). Global scale climate-crop yield relationships and the impacts of recent warming. Environmental Research Letters. 2, 004000. 7 pages.*
30. *Ludi, E., Getnet, M., Wilson, K., Tesfaye, K., Shimelis, B., Levine, S., Jones, L. (2011). Preparing for the future? Understanding the influence of development interventions on adaptive capacity at local level in Ethiopia. London: ACCRA.*
31. *Lyon, B. and DeWitt, D.G. (2012). A recent and abrupt decline in the East African long rains. Geographical Research Letters. 39: L02702.*
32. *Markos, E. (1997). Demographic Response to Ecological Degradation and Food Insecurity in Drought Prone Areas in Northern Ethiopia. Ph.D. Thesis, The University of Groningen.*
33. *Matson, P.A., Naylor, R.L. and Falcon. W.P. (2005). Analysis of wheat yield and climatic trends in Mexico. Field Crops Research. 94: 250–256.*
34. *MoARD (2009). Food Security Program 2009-2014. Addis Ababa: MoARD.*



36. MoARD [Ministry of Agriculture and Rural Development] (2008). *A Study on Causes of Resettlers' Food Self-insufficiency. Draft Paper.* MoARD Food Security Coordination Office. Addis Ababa: MoARD.
37. MoFED [Ministry of Finance and Economic Development] (2010). *The Federal Democratic*
38. National Meteorological Agency] (2007). *Climate change national adaptation programme of action (NAPA) of Ethiopia.* Addis Ababa: MOWR/NMA. NMA [National Meteorological Agency of Ethiopia] (2012) *Weather station data. Obtained by request.*
39. NMA/IRI (2012). *Climate analyses and applications map room.* Online at: <http://213.55.84.78:8082/maproom/NMA/index.html>
40. Online at: <http://emdat.be/> Online at: <http://www.ajol.info/index.php/ejdr/article/view/686>
41. *Patterns over Eastern and Southern Africa during the 1997-2000 period.* *Journal of Climate.* 15:3096-3103.
42. Philippon, N.P., Camberin, P., and Fauchereau, N. (2002). *Empirical predictability study of October-December East African rainfall.* *Quarterly Journal of the Royal Meteorological Society.* 128: 2239-2256. Rajabi, A. and Ober, E.S. (2012). *Breeding for improved drought tolerance,* in Ashraf, M. et al. *Crop production for agricultural improvement,* Dordrecht: Springer, pp. 43-56.
43. *Protection]* (2013). *Information provided by Dr. Muktar Reshid. Lobell D.B., Ortiz-Monasterio, J.I., Asner, G.P.,*
44. ReliefWeb (2012). *Ethiopia.* Online at: <http://reliefweb.int/country/eth>
45. *Republic of Ethiopia: Growth and Transformation Plan (2010-2014/15), Draft Document: Addis Research Report No. 92.* Washington, D.C.: IFPRI. Williams, A.P., Funk, C., Michaelsen, J., Rausher, S.A., Robertson, I., Wils, T.H.G., Koprowski, M., Riche, B., Hachileka, E., Auwor, C.B. and Hammill, A. (2009). *Climate-related vulnerability and adaptive capacity in Ethiopia's Borana and Somali communities.* London: Save the Children UK, Care International, IISD and IUCN.
46. Segele, Z.T. and Lamb, P.J. (2005). *Characterization and variability of Kiremt rainy season over*
47. Senait, R., Givey, C., and Castillo, G. (2010). *The rain doesn't come on time anymore: Poverty, Vulnerability, and Climate Variability in Ethiopia.* Addis Ababa: Oxfam International.
48. Simane, B. (2017) *Climate Change Induced Vulnerability of Smallholder Farmers:*
49. Stocker, T., Qin, D., Plattner, G.-K., Tignor, M., Allen, S., Boschung, J., Midgley, P. (Eds.). (2013). *Summary for policy makers. Climate change 2013: The physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom: Cambridge University Press.
50. Stoner, A. M. K., Hayhoe, K., Yang, X., & Wuebbli Tolossa, D. (2008). *Livelihood transformation from pastoralism to agro-Pastoralism as adaptation strategy among the Urrane of North-Eastern Ethiopia.* *Quarterly Journal of International Agriculture.* 47(2): 145-166.
51. Tolossa, D. (unpublished) *Building resilience to climate change. Research activities with Addis*
52. UN [United Nations] (2010). *World Population Prospects, the 2010 Revision.* Online at:
53. UNDP [United Nations Development Programme] (2011). *Human Development Report 2011.* New York: UNDP.
54. USAID [United States Agency for International Development] (2005). *Recent drought tendencies in Ethiopia and equatorial subtropical Eastern Africa.* Washington D.C.: USAID.
55. USAID and DRMFS (2010). *An Atlas of Ethiopian Livelihoods.* Addis Ababa: USAID/DRMFS.
56. USGS and USAID (2012). *A climate trend analysis of Ethiopia. Informing Climate Change Adaptation Series.* (Retrieved from http://pubs.usgs.gov/fs/2012/3053/FS12-3053_ethiopia.pdf)
57. Verdin, J. and Klaver, R. 2002. *Grid cell based crop water accounting for the famine early warning system.* *Hydrological Processes,* 16:1617-1630.
58. Webb, P., von Braun, J., and Yohannes, Y. (1992). *Famine in Ethiopia: Policy Implications of Coping Failure at National and Household Levels.* International Food Policy Research Institute.
59. Woldeamlak, B. (2009) *Rainwater Harvesting as a Livelihood Strategy in the Drought-Prone Areas of the Amhara Regions of Ethiopia.* Addis Ababa: Organization for Social Science Research in Southern and Eastern and Southern Africa.
60. World Bank (2006). *Ethiopia: Managing water resources to maximise sustainable growth.* Washington, D.C.: World Bank.