TECHNICAL REPORT

CLIMATE VARIABILITY AND CHANGE IN ETHIOPIA

SUMMARY OF FINDINGS

DECEMBER 2015

This document was produced for review by the United States Agency for International Development. It was prepared by Chemonics for the ATLAS Task Order.

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Cover Photo: Check dams used to slow runoff in kebele of Dire Dawa Administration, helping to control erosion and increase water capture (Elizabeth Strange)

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United States Agency for International Development

Climate Change Adaptation Thought Leadership and Assessments (ATLAS)

Prepared by:

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CONTENTS

LIST OF TABLES AND FIGURES

ACRONYMS

ATLAS	Climate Change Adaptation Thought Leadership and Assessments
CRGE	Climate Resilient Green Economy
CSI	Country Specific Information
DFAP	Title II Development Food Assistance Program
FFP	Food for Peace
FSCF	Food Security Country Framework
CHIPRS	Climate Hazards Group Infrared Precipitation with Stations
CRU TS	Climate Research Unit Time Series
PES	Payment for Ecosystems Services
PSNP	Productive Safety Net Programme

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EXECUTIVE SUMMARY

Climate variability and climate change likely are significant contributing factors in the food security challenges Ethiopia currently experiences and will experience going forward. The USAID Climate Change Adaptation Thought Leadership and Assessment (ATLAS) activity has undertaken field work and analysis to provide guidance to the Food for Peace (FFP) program in Ethiopia aimed at identifying and prioritizing climate risk and developing interventions that effectively address food security in light of climate risk.

Traditional rural livelihoods in Ethiopia, including agriculture, pastoralism and agro-pastoralism, are highly sensitive to climate variability and climate change because of their close links to the natural environment. Furthermore, the ecosystems on which these livelihoods rely face substantial non-climate stressors related to intensity of natural resource use, uneven management practices and conflicts between competing uses. Climate variability and climate change exacerbate these challenges.

ATLAS sought to provide practical information to guide FFP program development in Ethiopia over the five-year time period of the planned FFP program. ATLAS focused on four areas of Ethiopia, including: (a) northeastern Tigray region, (b) central Amhara region, (c) Dire Dawa and northeastern Oromia region and (d) the southern Oromia region and Southern Nations, Nationalities and Peoples' region. Given the inherent uncertainty regarding climate projections in this short timeframe, it makes sense to examine historical climate trends to help determine priorities for future FFP interventions. Historical data indicate that:

- Rainfall is increasingly erratic, with marked seasonal deficits when compared to long term past averages
- Droughts appear to be increasingly frequent
- Heavy rainfall events appear to be increasingly frequent, with changes in rainfall patterns, including decreased reliability and less predictability
- Temperatures are increasing
- The number of extreme events is likely to increase

Other observations from the ATLAS work include:

- Recognition that adaptation activities are already being implemented by donors, the Ethiopian government and individual households, but these could be strengthened through a systematic evaluation of climate risks
- Limited livelihood diversification, coupled with a lack of off-farm income, especially among women and an increasing number of landless youth, poses significant challenges to the country
- A lack of climate change information and expertise to support food security interventions, particularly locally-relevant data and analyses is a significant challenge

ATLAS examined several priority issues for which the links between (a) food security and traditional livelihoods and (b) climate variability and climate change in Ethiopia are substantial, including:

- Impacts on pests and pathogens: increases in temperature and changing rainfall patterns likely will increase the populations and ranges for some agricultural pests and waterborne pathogens, requiring changes to crop and livestock management practices, more aggressive adoption of integrated pest management practices and introduction of new inputs to counter more virulent challenges.
- Impacts on nutrition: increased atmospheric CO_2 has been shown to reduce the nutrient content of crops, creating nutritional challenges. At the same time, warming surface and groundwater increases the prevalence of waterborne pathogens that cause diarrheal disease.
- Impacts on groundwater availability: in most cases, groundwater supplies are directly linked to surface water and rainfall, with groundwater recharging through soil infiltration. When surface water sources become insufficient due to decreased replenishment and/or increased evaporation rates, groundwater exploitation increases. However, groundwater recharge rates generally are insufficient to meet sustainable demand, leading to decreased water quality and increased pumping depths (and associated increased costs).
- Climate and disasters in the intervention areas: climate shocks, including droughts and catastrophic flood events likely will increase with climate variability and climate change, requiring more sophisticated climate shock early warning systems, better public outreach and better mapping of historical shocks to inform decision making on investments in infrastructure and technical assistance to blunt the impact of future shocks.

To be effective, adaptation responses to address the risks associated with climate variability and climate change must take into account projected impacts on agriculture and natural ecosystems, as well as impacts on socio-economic systems and their dynamics. Projected impacts also vary between geographic areas. Therefore, it is critical that adaptation responses are tailored to the specific environmental, socio-economic and cultural conditions of a particular areas or community.

Important areas of intervention that address climate variability and climate change include:

- Watershed management and rangeland rehabilitation that explicitly recognize climate stressors to the health and efficient function of their systems
- Livelihood diversification that recognizes the preeminence of traditional agricultural and pastoralist livelihood strategies, but seeks to introduce complementary livelihood strategies that make household more resilient to climate shocks and long term climate trends
- Outreach and building capacity on appropriate farm technologies and practices, including green manure/cover crops, improved seed varieties and other innovative on-farm management practices
- Recognition of ecosystem carrying capacity constraints when considering investments in agricultural and pastoralist interventions

- Investment in institutional capacity building that strengthens the foundation for government and private sector stakeholders and households to effectively plan for a changing climate and to be resilient to climate shocks

INTRODUCTION

CONTEXT

The USAID Adaptation Thought Leadership and Assessment (ATLAS) project aims to improve the quality and effectiveness of USAID's and countries' development programs to reduce climate risks through: tested and harmonized approaches to adaptation assessment; thought leadership; and capacity building of USAID and its partners. In doing so, the project promotes adaptation to climate change and integration of adaptation into other economic investments, to safeguard and promote sustainable, climate resilient growth. A wide range of approaches to vulnerability and adaptation assessment exists, but there is a need to identify good practices or standards to help people design adaptation assessments effectively and get useful information from them. As such, ATLAS guides USAID Missions and their partners to the best tools for assessing risks and evaluating adaptation options and help synthesize best practices. ATLAS emphasizes fit-for-purpose assessments and the uptake of information so that it builds capacity to translate information into adaptation investment decisions and actions at the country, sector, and program levels.

Under ATLAS Activity 1.4: Assessment of Climate Risks to Food for Peace (FFP) and Conservation Investment, Chemonics is providing climate risk input to USAID to support the development of the new Food Security Country Framework (FSCF) and Country Specific Information (CSI) documents for Ethiopia for funding under the Title II Development Food Assistance Program (DFAP). This report presents key findings from field visits in Ethiopia and a desk review that address specifically climate risks and food security in current and proposed DFAP intervention regions.

METHODS

ATLAS conducted field visits and consultations, as well as subsequent climate analyses for four areas, including locations where FFP interventions are currently being implemented. The areas are, as shown in Figure 1 below: (1) northeastern Tigray region; (2) central Amhara region; (3) Dire Dawa and northeastern Oromia region; and (4) the southern Oromia region and Southern Nations, Nationalities and Peoples' region. Table 1 further outlines the specific sites visited within these regions.

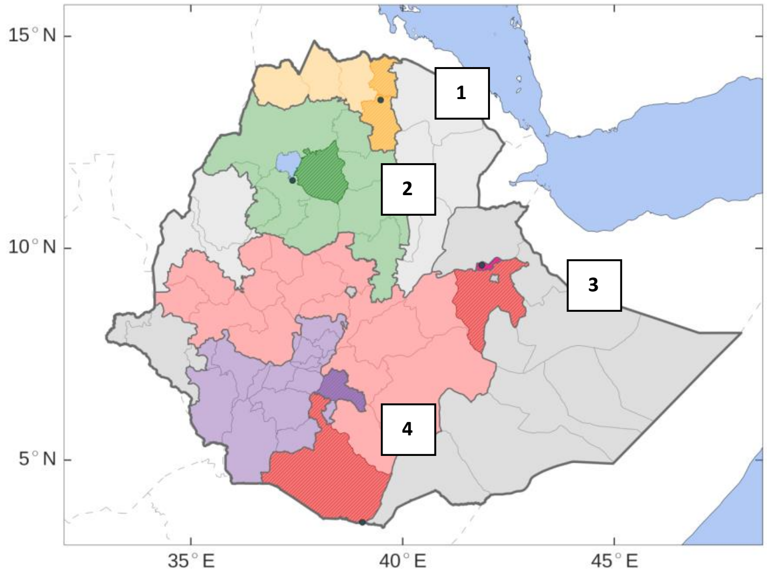


Figure 1: Map showing management districts in Ethiopia with the FFP areas highlighted. See Table 1 for details of each area. Black dots indicate locations of available weather stations relevant to the FFP areas.

Table 1: Details of the FFP areas. See Figure 1 for map of geographical locations.

MAP ID	NAME	DETAILS OF REGION
1	Northeastern Tigray region	East Tigray Zone (Gulomekeda Woreda) South Tigray Zone (Olfa and Raya Azebo Woredas) Mek'ele Zone Misraqawi Zone (Kilte Awulaelo, Hawzen and Ganta Afeshum Woredas)
2	Central Amhara region	South Gondar Zone (Simada and Lay Gayint Woredas) Bahar Dar Zone
3	Dire Dawa region & northeastern Oromia Region	Entire Dire Dawa region East Haraghe Zone (Kersa Woreda) of Oromia
4	Southern Oromia Region & Southern Nations, Nationalities and Peoples' Region	Borena Zone (Yabelo Woreda) Sidama Zone (Hawasa City, Awasa Zuria Woreda)

KEY CHALLENGES

Although the problems the regions face are varied, several common themes exist:

- **Rains are increasingly erratic, with marked seasonal deficits, coupled with more frequent drought and heavy rainfall events**. The changing dynamics are associated decreases in crop and livestock production and increasing food deficits. Field consultations indicated that both DFAP implementing partners and beneficiaries are concerned about changes in temperature and precipitation.

- **Adaptation activities are already being implemented, but could be strengthened through a systematic evaluation of climate risks**. Although climate change is seldom explicitly considered in DFAP public works products, the projects promote adaptation through, for example, projects focused on watershed restoration, water harvesting, small-scale irrigation, soil and water conservation, and conservation agriculture. Nevertheless, an explicit and systematic evaluation of climate risks with respect to these activities could offer important insights on new actions that could improve beneficiaries' resilience to climate risks.
- **Limited livelihood diversification, coupled with a lack of off-farm income, especially among women and an increasing number of landless youth, poses significant challenges for the region.** Livelihood alternatives are largely limited to public works projects supporting landless youth and a few small businesses such as milk distribution centers. In some areas, work with women's groups are helping to build savings and providing critical access to credit, as well as some off-farm sources of income such as sale of cook stoves. However, few small business opportunities are promoted for women. The lack of skill development and livelihood diversification seriously limits adaptive capacity in all of the intervention areas.
- **A lack of climate change information and expertise to support DFAP projects exists, particularly locally-relevant data and analyses.** This is a major impediment to greater consideration of climate change in DFAP projects.

OVERVIEW OF CLIMATE AND FOOD SECURITY LINKAGES

Rural livelihood systems of Ethiopia – crop cultivation, pastoralism and agro-pastoralism – are highly sensitive to climate. Food insecurity patterns are seasonal and linked to rainfall patterns, with hunger trends declining significantly after the rainy seasons. The increasing year-to-year climate variability and increases in both droughts and heavy precipitation events lower agricultural production with negative effects on food security. Climate related shocks affect productivity, which together with low levels of technology and high poverty leave people with little choice or resources to adapt. The effects of sudden and/or recurrent shocks such as droughts are compounded by these ongoing, long-term stresses. These changes also hamper economic process and exacerbate existing social and economic problems. The result is that the long-term stresses deplete household resilience to the point where traditional coping strategies become non-viable.

From a climate perspective, crop production (yield and successful harvesting) depend on the:

- Soil moisture availability
- Amount of rainfall
- Timing of the start of the rains
- Length of the rainy season
- Hot spells during key stages of the growing season
- Cold spells during key stages of the growing season
- Length of dry spells during key periods of the growing season (e.g., erratic rainfall)
- Occurrence of damaging heavy rainfall at key stages of the season (e.g., extreme rainfall)

Crop yields are typically strongly sensitive to climate under marginal conditions. In marginal conditions crops are relatively near to a point of failure and will fail if rainfall falls below a certain threshold. Below this threshold other farming strategies become increasingly less relevant as fundamental soil moisture content cannot be maintained. In less marginal conditions, crop yields are often more directly related to farming strategies such as fertilizers, pest control, and seed variety selection.

It is critical to note that for crop production, it is actually soil moisture that is the key variable, not rainfall. While there is a very strong link between soil moisture and rainfall, other variables such as soil depth, slope, temperature, and winds strongly influence soil moisture conditions. In many locations the primary threat to soil moisture is increased temperature as this increases evaporative losses both directly and through transpiration. Uncertainty in future rainfall amounts is therefore often of less relevance than sometimes thought, as increasing temperatures can result in soil moisture deficits even under increased rainfall conditions.

Access to markets for both buying and selling is impacted by flooding events that damage roads and other infrastructure. Extreme temperature events, as well as sustained high temperatures, further affect people's ability to work in the fields, especially in the context of small-scale farmers where the labor is conducted manually.

Food security can also be considered at different scales ranging from the field scale through to the regional scale. From a climate perspective, droughts can have different areal impacts. Some droughts are relatively local and have limited regional impact. Other droughts are spatially extensive and can impact a whole region reducing the possibility of using regional food trade to alleviate food security crises.

The FFP areas share challenges such as population pressure, environmental degradation and unreliable water supplies. These conditions exacerbate the adverse impacts of climate change. The factors contributing to agricultural sector vulnerability to climate variability and change in these areas include:

- Limited technical resources on improved farm and pasture management
- Limited assets and few, if any, alternative sources of income
- Small farm size/poor pasture
- Dependence on rain-fed crop production/rangelands with few water points
- Lack of access to credit

Climate change, climate change vulnerability and climate shocks negatively impact food production:

- Rising temperatures, increasingly erratic rainfall, shortened rainy seasons, and lower amounts of seasonal rains are reducing crop production (Figure 2).
- High temperatures and low rainfall reduce pasture and water availability for livestock.
- Floods and droughts damage crops and farmlands, injure and kill livestock, and can lead to complete loss of annual production.
- Periods of recurrent and prolonged drought indicate the potential for cumulative impacts – whereby the effects of sudden and/or recurrent shocks are compounded.
- Increased occurrence of extreme rainfall events alters water availability.

Exposure to climate risk is increasing in many of the areas studied:

- Both *belg* and *kiremt* rainy seasons are contracting, reducing the amount of seasonal rain available for crop production (Funk et al., 2012).
- *Belg* rains are increasingly unpredictable, leading farmers to make risk-averse planting decisions that produce below-average yields and loss of income (Funk et al., 2012).
- Recent analyses of regional trends indicate a decline in March-September rains in the northeast since the mid-1960s; rainfall declines in the southeast since the 1980s, with recent years particularly dry; and rainfall declines in the southwest rainfall since the 1960s, accelerating since the mid-1990s (Funk et al., 2012).
- Floods and droughts have already become more intense and frequent.

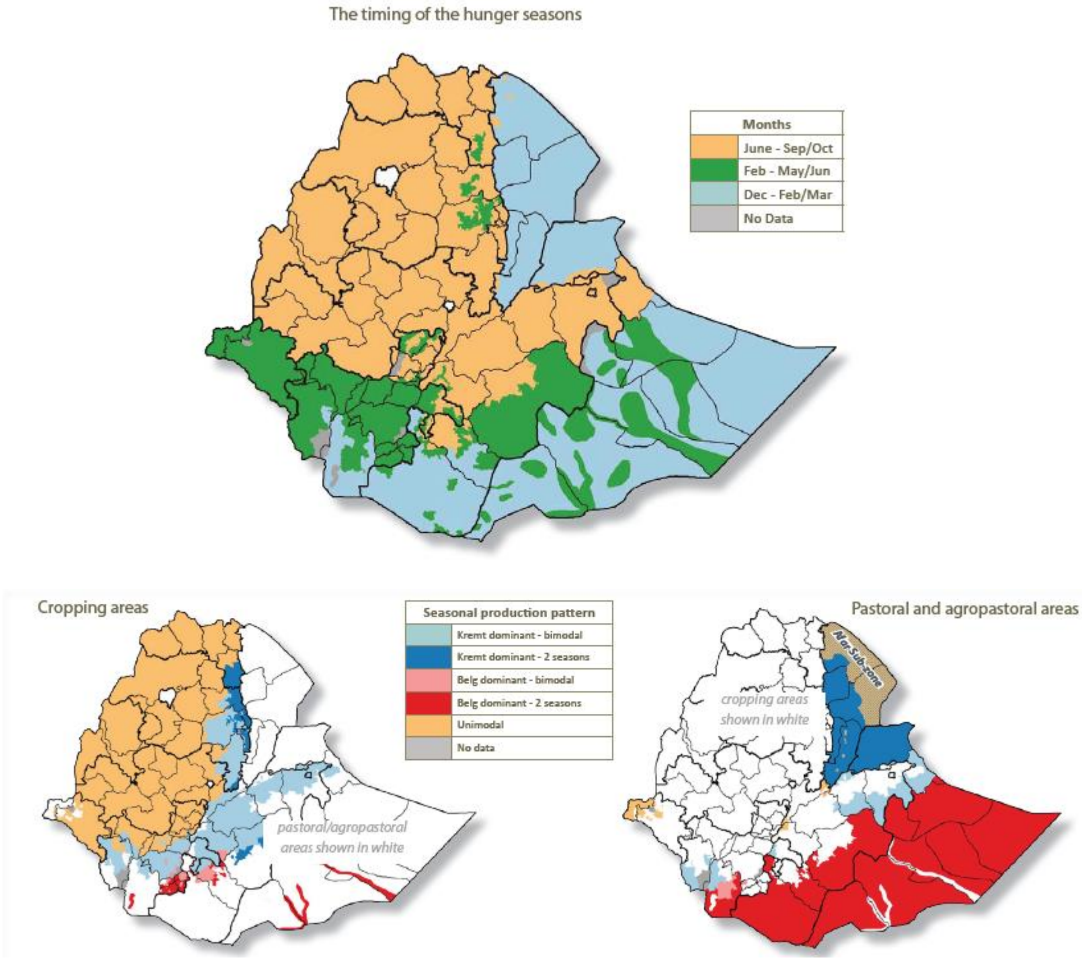


Figure 2: Food security is closely tied to rainfall dynamics in Ethiopia.
(USAID and DRMFSS, 2010)

Analysis of historical climate trends can provide useful insights into the current trajectory of various climate variables, particularly on shorter-term planning horizons. Changes observed in the seasonal climate of Ethiopia during the 1981-2014 period were examined across the three predominant rainy seasons: *kiremt* (June through September), *bega* (October through December) and *belg* (March through May) using rainfall and temperature data from Climate Hazards Group Infrared Precipitation with Stations (CHIRPS)[1] (Peterson et al., 2013) and Climate Research Unit Time Series (CRU TS) 3.21[2] (University of East Anglia, 2013; Harris, Osborn, & Lister, 2014).

In summary, the available evidence for Ethiopia suggests climate variability is manifested through:

1 The Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) data is made up of daily rainfall data. It is a combination of satellite and weather station rainfall data and is available for the period 1981-2014 and at 0.05 x 0.05 degree spatial resolution.

2 The Climate Research Unit Time Series (CRU TS) data is made up of monthly time series of various climate variables, which include maximum and minimum temperature and rainfall. The data, which is based on over 4000 global weather stations, is available for the period 1901 – 2012 and is gridded to 0.5 x 0.5 degree spatial resolution.

- **Increased temperatures**. Incremental but also linked to more intense heat waves and higher rates of evapotranspiration. By themselves, these increases in temperature can affect many aspects of local economic development and agricultural productivity. For example, warmer temperatures and increased evapotranspiration can:
  - Exacerbate tensions that already exist between agricultural and livestock interests as well as other uses of water, especially during the dry season, where these changes will become more pronounced
  - Alter the quality of water available. Water requirements primarily are met using surface water from rivers and streams and, less importantly, groundwater from wells. Increases in temperatures could negatively impact water quality from these sources by increasing waterborne pathogen populations
  - Increase plant stress and yield reductions because of increased evaporation and increased pest pressures.
- **Likely increases in the number of extreme events**. The future of precipitation for the region in a changing climate is uncertain. This is due to large uncertainties in the projections available on the global circulation models, partly because of their low spatial resolution. Despite these uncertainties, it is clear that in the future, significant increases in climate variability and extreme events such as droughts and floods can be expected. The impacts of these changes are already significant, not only in human costs but also in economic and financial terms.
- **Changes in rainfall patterns, including decreased reliability and less predictability** (see Figure 3). Rainfall trends were calculated over the period 1981-2015 using the CHIPRS rainfall product and evaluated according to annual totals as well as other characteristics of relevance such as intensity and duration. A large proportion of Ethiopia's production is harvested in areas where more rain falls in *belg* than in *meher*. The late arrival and general un-reliability of the *belg* rains, which occur between February and May, implies significant impacts to food security. By itself, this dynamic is:
  - Positively correlated with cereal yields, with wetter years linked to higher yields, particularly during April-May, which highlights the importance of the *belg* rains to food security.
  - Negatively correlated to food prices. Lower production is linked to higher food prices, particularly after the *belg*.

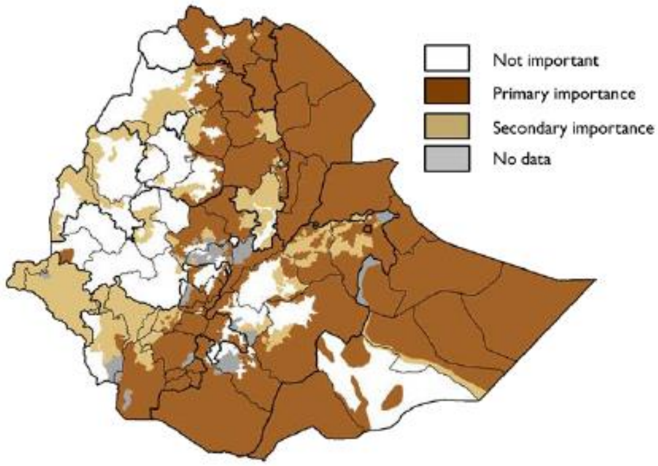


Figure 3: Areas where lack of rain or erratic rain is considered to be a key factor in contributing to vulnerability (USAID and DRMFSS, 2010)

Other common problems and pressures (climate and non-climate) for the regions are outlined below:

- **Droughts**: remain one of the key drivers of food insecurity in Ethiopia. Since 1950, 12 major drought-induced food security crises have occurred. The main impacts of droughts include crop damage, loss of pasture and water sources, loss of animals, hunger, disease outbreaks, asset depletions, malnutrition and migration. Droughts can result in sharp reductions in agricultural output and related productive activity and employment, with multiplier effects on the monetary economy.
- **Floods**: both riverine and flash floods, regularly cause crop and infrastructure damage, contribute to farmland degradation and erosion and cause loss of life.
- **Low productivity and social inequality**: poverty, limited economic base and low levels of education hinder the ability of people to adapt. The productive systems of agriculture and livestock are the pillars of the economy. However, land shortages, limited resources and gaps in the dissemination of knowledge continue to limit the productivity of these systems.
- **Land degradation**: factors such as deforestation, erosion, poor agricultural practices, among others, have led to the degradation of soil. Under these circumstances, and combined with the intensification of the variability and climate change, the problems of soil degradation and water already jeopardize the sustainability of areas dedicated to subsistence.
- **Fluctuations in water availability**: natural sources of water include rivers, lakes, groundwater, streams, creeks and rainfall. The effective use of water resources is essential. However, with changes in the intensity of rainfall, significant changes in periods of drought and displacement of periods of precipitation are also seen.

Several of the above stressors are discussed in detail in subsequent sections of this document.

CURRENT CLIMATE IMPACTS IN THE INTERVENTION AREAS

Field visits and consultations were conducted in the four areas, including where FFP interventions are currently being implemented as well as potential new areas considered for intervention. During these field visits and consultations climate change related questions were asked on an ad hoc basis. The following questions were asked more or less routinely during the location visits, and the findings from these are presented below in Tables 2:

- How is food security in the area affected by climate variability and change?
- What climate shocks have occurred and how have they affected food availability and access?
- What sources of information are available to better understand these shocks (e.g. in terms of frequency of occurrence, intensity of impact)?
- What program activities help promote resilience to climate shocks and what additional measures are needed?

Table 2: Summary of climate hazards, impacts, and consequences for each area

REGION	CLIMATE HAZARDS	IMPACTS	CONSEQUENCES
Northeastern Tigray region	Drought (low rainfall, late onset) Heavy rainfall Early cessation of rainfall	Extensive crop damage Decreased yield Loss of water points and pastures	Food shortages Reliance on the need to purchase food Vulnerability to malnutrition, financial stress, inflation, labor migrations and social unrest
Central Amhara region	Increase in the frequency of droughts Hail storms and heavy rain/floods Erratic rainfall Changes to timing and duration of seasonal rains	Crop damage/low production, livestock disease, loss of grazing land Damaged crops and dwellings/properties Soil erosion, loss of soil fertility and water-logging of fields	Loss of assets and income
Dire Dawa region & northeastern Oromia Region	Low seasonal rains and recurrent droughts Erratic rainfall Flash floods	Major food shortage Depleted water sources	Sale of household assets including oxen and other livestock Migration in search of non-farm labor opportunities Water and sanitation crisis

REGION	CLIMATE HAZARDS	IMPACTS	CONSEQUENCES
			Major loss in life and an increase the number of homeless individuals
Southern Oromia Region & Southern Nations, Nationalities and Peoples' Region	Frequent droughts	Decreased livestock production Farmers revert to selling livestock Migration in search of pastures and water	Milk shortages, poor nutrition among children and lactating mothers Total dependence on external food assistance Depletion in herds, reduction in short term productivity and long-term genetic diversity Conflict among neighboring clans

A subsequent analysis exploring some of the likely first order linkages between climate and food security in Ethiopia, with a focus on core climate variables was conducted. The approach used in the analysis is to explore historical trends and variability (Table 3), combined with future climate model based projections. The result of this work is summarized in subsequent sections.

Table 3: General trends in climate-related dynamics for all FFP areas, including potential adaptation responses[3]

HAZARD	OBSERVED TRENDS	TRENDS PROJECTED	IMPACTS (PRODUCTION, WATER AVAILABILITY, ACCESS)	POTENTIAL ADAPTATION RESPONSES
Higher Temperatures	Mean average temperature increase of 1.3°C – most rapidly increasing between July-September	Mean annual temperature is projected to increase by 1.1 to 3.1°C by the 2060s	Reduced soil moisture availability Reduced water availability. Reduced water quality Changes to timing and distribution of agricultural pests.	• Integrated climate smart practices including green manure • Improved water resource management from larger springs, deep hand dug wells and boreholes • Improved water quality surveillance particularly during the peak of the dry season in areas with shallow wells and unimproved water sources • Surveillance systems that include pest monitoring during critical periods
	Increased frequency of hot days (increased by 73 (an additional 20% of days)	Increased number hot days will occur on 19-40% of days by the 2060s, especially July-September		

[3] The trends themselves vary regionally and are further described in Table 2 above.

HAZARD	OBSERVED TRENDS	TRENDS PROJECTED	IMPACTS (PRODUCTION, WATER AVAILABILITY, ACCESS)	POTENTIAL ADAPTATION RESPONSES
Changes in Rainfall Patterns	Rainfall patterns increasingly more erratic, with decreased reliability and failure of *belg* rains	Continued erratic patterns	Decreased reliability of unimproved groundwater sources and surface water during droughts or a prolonged dry season is likely	• Water mapping – targeting drought proofing measures such as well deepening and rehabilitation of water supply. • Assuring routine maintenance of pumps
			Reduced Crop productivity or failure	• Introducing programs/projects that promote improved farming practices, drought-resistant and early maturing crop varieties, and supply inputs that increase crop yield and productivity • Improving farmers' knowledge about proper use of weather information in carrying out agricultural activities to avoid risks of climate change • Introducing/supporting off-farm or non-agricultural alternative livelihood activities
	Changes in timing and intensity of rainfall patterns		Potential for new ecological niches for plant pests and diseases.	• Improved understanding of potential pest risks and developing appropriate and timely response measures
Drought			Reduced agricultural output or crop damage.	• Early warning systems to properly respond to risks • Improving farmers' knowledge about proper use of weather information in carrying out agricultural activities to avoid risks of climate change • Livelihood diversification – introducing/supporting off-farm activities to increase alternative household income sources
			Loss of pasture and animals	• Small scale irrigation to buffer against peak drought

HAZARD	OBSERVED TRENDS	TRENDS PROJECTED	IMPACTS (PRODUCTION, WATER AVAILABILITY, ACCESS)	POTENTIAL ADAPTATION RESPONSES
			Hunger	• Livelihood diversification
Floods			Damage crop and infrastructure, contribute to erosion and farmland degradation	• Integrated watershed management including reforestation, furrow irrigation, canals, use of rope and washer pumps, hand-dug wells, motor pumping from rivers

IMPACTS ON PESTS AND PATHOGENS

In general, food crops are sensitive to climate change, altering crop physiology and resistance to diseases. Such change, which affects soil temperature and moisture levels, also determines the vitality of both beneficial organisms and pests. Although a comprehensive understanding of crop-pest-climate relationships is lacking, the available evidence clearly suggests that climate change will alter crop productivity by:

- Increasing temperatures, which have been shown to:
  - — Change the timing and duration of migration patterns (flight phenology) of vector species, increasing the spread of plant pathogens and therefore the timing and number of applications of agricultural inputs such as fertilizers and pesticides.
  - — Lengthen the breeding season and increasing the reproductive rate of some agricultural pests.
  - — Expand the altitudinal range of crop pests, particularly into current cold limited areas (highlands). For example, the coffee berry borer (*hypothenemus hampei*) may extend to highland Arabica coffee producing areas.
- Changing rainfall patterns linked to changes in migratory patterns of the desert locust (*schistocerca gregaria*).
- Creating new ecological niches, potentially allowing for the establishment and spread of plant pests and diseases to new geographical areas and from one region to another.
- Changing the application rate and use of pesticides. Evidence from tomato, cotton potato and other crops suggests that a rapidly changing onset of pest outbreaks could require 2-4 additional sprays (with cost and management implications) in the future (Fahim et al., 2007 and Fahim et al., 2010)
- Increasing a threat from late blight due to earlier onset of warm temperatures, which could result in the the potential for more severe epidemics and increases in the number of fungicide applications needed for control.
- Affecting rainfall characteristics. For some diseases, rainfall characteristics (e.g. intensity, onset, duration) other than the amount that falls are a more important determinant of disease progress. Septoria leaf blotches of cereals, for example, are spread through rain-splash – a process greatly enhanced during periods of heavy rainfall.

In light of these projected changes, it is clear that adapting to the increased risk of plant pests and diseases under a changing climate will require changes to current farming practices including early detection and identification of specific diseases, as well integrated pest management to contain disease spread. It is clear that additional research is required on improved surveillance methods, epidemiological knowledge and information on biological control organisms and mechanisms.

IMPACTS ON NUTRITION

The term “malnutrition” indicates various forms of undernutrition that are caused by many factors, including dietary inadequacy, infections, and socio-cultural factors. Undernutrition includes stunting, wasting, and deficiencies of essential vitamins and minerals, as well as obesity or over-consumption of specific nutrients (Ebi, 2015). According to the Intergovernmental Panel on Climate Change 5th Assessment Report (Niang et al., 2014), climate change is projected to increase the burden of malnutrition in Africa. This is because:

- Crops may become nutrient-limited in response to elevated CO_2 concentrations because increased CO_2 affects a plant’s ability to absorb nitrogen, a key nutrient to crop growth, which can constrain and reduce protein and micronutrient levels (such as zinc, and iron) in certain crops such as wheat.
- A more variable climate results in a changing dynamic of diseases, including diarrheal disease, that impact community health. When health is compromised, the ability to absorb nutrients from food decreases, with attendant implications for productivity and general well-being
- Heat waves are projected to increase and will have negative implications for the productivity of agricultural workers if they coincide with key stages of crop development

IMPACTS ON GROUNDWATER AVAILABILITY

Groundwater provides an important resource for meeting the dispersed demand of rural communities, particularly during droughts. Once surface rivers and streams dry, groundwater still provides a reliable source of water through wells, springs and boreholes. However, it is well known that water security is dependent on availability (volume stored or recharged in the aquifer), access (springs, wells or boreholes) and demand (linked to livelihoods strategies). In most areas, the key determinants of water security will continue to be related to access rather than availability. Extending access while recognizing and understanding groundwater conditions is critically important, and this requires an improved understanding of groundwater and recharge conditions, which are typically lacking in Africa. MacDonald et al. (2001) estimated groundwater availability for Ethiopia, indicating areas where groundwater use could be improved as noted in Figure 4; however, relatively little other work has been done to further unpack this information at more regional scales.

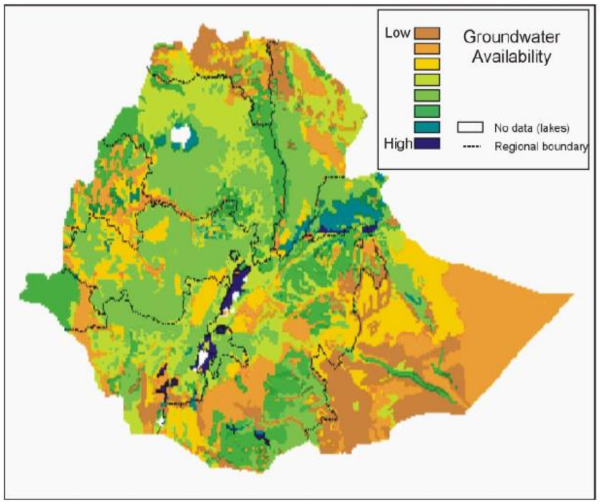


Figure 4: Map showing the estimated distribution of groundwater availability in Ethiopia
(MacDonald et al., 2001)

While quantifying the relationship between climate change and groundwater availability is complicated, what is clear is that changes in rainfall and evaporation translate directly to changes in surface water infiltration and groundwater recharge rates. Some key impacts of these changes include:

- Potential for decreased reliability of unimproved groundwater sources and surface water sources during droughts or a prolonged dry season
- Water points drawing from larger groundwater bodies such as larger springs, deep hand dug wells and boreholes can provide more reliable access to water across seasons generally, but even these reliable sources can fail during a drought due to:
  - Increased strain on pump mechanisms leading to breakdowns if maintenance is neglected.
  - Potential for falling water levels in the immediate vicinity of well or borehole – especially in areas of high demand.

As temperature increases have the potential to result in increased soil moisture deficits even under conditions of *increasing* rainfall, there is value in investing in an improved understanding of how to constrain or limit evaporation through activities related to water resource management such as small scale irrigation, and soil and water conservation.

Some example activities to address this challenge were recently noted in the Overseas Development Institute background paper on groundwater dynamics under a changing climate (Calow & MacDonald 2009), and include:

- **Water mapping – identifying vulnerable areas.** Maps can be used to highlight those areas likely to be most affected by changes in surface and groundwater availability during drought and help target drought proofing measures (e.g., rehabilitation of surface water sources, rehabilitation of groundwater recharge areas, groundwater well deepening). For example, groundwater monitoring in key areas could provide insights on changing reliability of boreholes, tracking recharge rates and water quality.

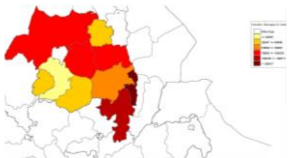
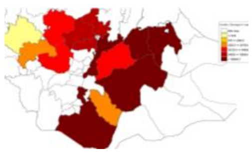
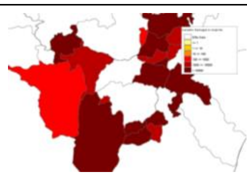
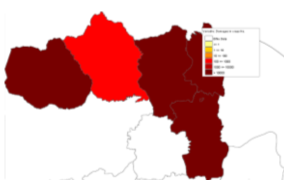
- **Livelihoods monitoring – responding to local needs.** To identify the most vulnerable areas and groups, local information is needed on the links between water resource availability and food security, including water related illnesses. Correlating these data with indicators of food insecurity can provide a clearer picture of livelihood security and point the way toward interventions needed to improve livelihood security related to water resource challenges. Interventions may include regular pump maintenance to assure water availability in the early stages of drought, or assistance with water transport in the later stages of drought.

In the near-term (i.e. over the next 5-10 years), given that it is extremely difficult to accurately predict climate trends, it makes sense to screen potential FFP interventions for their ability to respond to a range of climate variability based on historical observations and local experience. Interventions should be selected for resilience to a variable climate, including increasing periods of high and low rainfall, an increase in average temperatures (and in historical minimum and maximum temperatures) and evaporative losses, both directly and through transpiration. It also makes sense to give extra consideration to the impacts of temperature increase, and the implications for evaporation, and, in turn, water storage and soil moisture. As described in the analysis, both maximum and minimum temperature increases are already detectable, and likely to continue in the future. In order to ensure that FFP interventions safeguard crop production and food security, it therefore is important that increasing temperatures and consequent increasing evaporative losses, both directly and through transpiration, are considered.

CLIMATE AND DISASTERS IN THE INTERVENTION AREAS

Knowing the timing and impact of extreme events across regions can help to policy makers, planners and crisis responders target adaptation interventions appropriately. Table 4 provides an analysis of the damage to crops and loss of livestock from climate related events by area and points to specific periods of time when these hazards occur by region. Table 4 data is sourced from Ethiopia's Disaster Information System (available through http://www.desinventar.net/) which registered and catalogued over 14.000 disasters across the country from 1957-2012. Understanding the historical and temporal dynamics of these shocks highlights the impacts on the food system and points the way to the timing of potential interventions. This information also helps determine the relative investment necessary to address one or more existing hazards by region.

Table 4: Crop damage by geographic area and source

REGION	CROP DAMAGE (HAS)	DOMINANT HAZARD IN CROP LAND DAMAGE	SEASONAL DYNAMICS OF HAZARD	DOMINANT HAZARD CONTRIBUTING TO LOSS OF CATTLE
Amhara		Flood 100%	August-September Corresponding to *kiremt* season	Hailstorms
Oromia		Fire 82% Floods 14%	Fires: September Floods: March September (peaking April, August and September during *kiremt* rains)	Drought
SNNPR		Drought 13% Flood 12%	Floods: September to December	Flood
Afar		Drought 53% Floods 47%	Drought: March and September Floods: July-November (peaking in September)	Floods
Tigray		Drought 58% Flood 35% Hailstorms 8%	Drought: September Flood: June-December (peaking July and August) Hailstorm: July-September (August peak)	Hailstorms

PROJECTED FUTURE IMPACTS

Climate trends should be viewed in dynamic terms, starting with the problem of current climate variability and extreme events (the adaptation deficit) as well as considering future climate change uncertainty. The trend analysis is spatially variable across the four areas and is summarized in Table 5 below. These trends suggest several potential areas where climate risks could be addressed in the short term, but they also suggest a high degree of uncertainty, especially around changing rainfall dynamics. Nevertheless, they clearly indicate that temperatures will continue to increase, and that these will increase evaporation and soil moisture deficits both in the near and the long term, which will not be offset by any of the projected changes in rainfall dynamics (Figure 5). Addressing these changes is therefore imperative in terms of crop and field management.

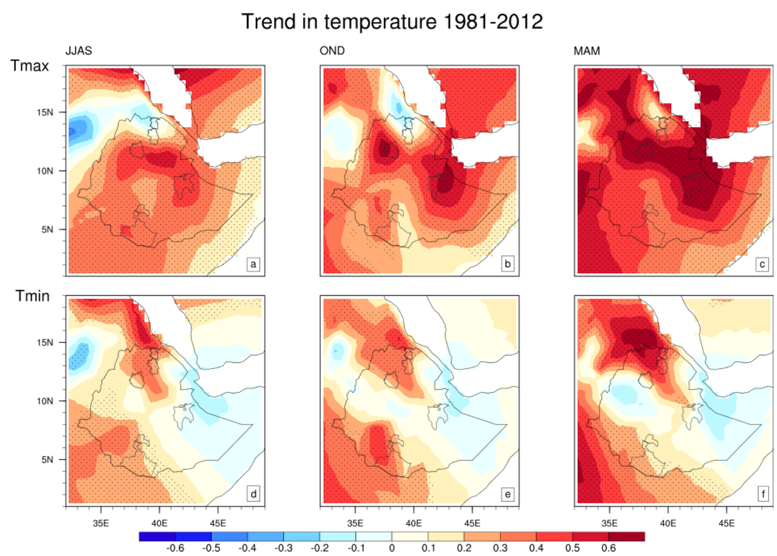


Figure 5: Decadal trends on seasonal mean maximum (a, b, c) and minimum (d, e, f) temperature across Ethiopia based on CRU TS3.21 data over the period 1981-2012. The seasons (June-Sept, Oct-Dec, March-May) are indicated at the left top side of the panels. Stipplings indicate regions where trends are statistically significant at the 95th percentile level (University of East Anglia, 2013).

In the long term future (2050-2100), high resolution climate models project a general drying trend across the south and south east of the country with a possible wetting trend in the north. However, increased temperatures are very certain and the resultant impact on evaporation is very likely to have strong impacts on soil moisture and therefore agriculture and other related activities, particularly during the critical *kiremt* rains (Figure 6).

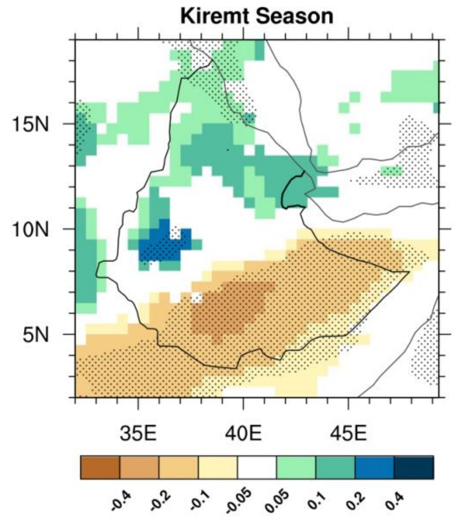


Figure 6: Changes in *kiremt*-season precipitation (shaded, unit: mm day −1) as projected by the high-resolution CMIP5 models. The precipitation changes are calculated as the difference between the simulations under the RCP 4.5 scenario (2050-2099) and the historical run (1950-1999). Only the grid cells with more than 70 % of the high-resolution models agree on the sign of precipitation change are shown. The stippled are the grid cells where precipitation change is significant at 90 % confidence level (Li, 2015).

Table 5: Summary of regional trends in rainfall and temperature

REGION	TEMPERATURE TRENDS (1981-2014)	RAINFALL TRENDS (1981-2015)
Amhara	Hotter maximum temperatures during *kiremt* (June-September) (+0.4-0.6°C/decade) *Belg* season temperatures (March-May) showing more rapid increases (> 0.6°C/decade).	• Increased rainfall with more consecutive dry days indicate increased intensity and possibly more frequent heavy rainfall • Some suggestion of increased core seasonal rainfall but very little evidence of other changes to rainfall characteristics
Oromia North East	Hotter – with more rapid increases in later part of *belg* (March-May) (0.6°C/decade) – but significant increases in the *kiremt* (June-September) (+0.4-0.6°C/decade)	• Intensification of drier conditions for the first rainfall season (March-May). • Intensification of wet events during *kiremt* (June-September) • Tentative evidence of decreasing and more erratic short season (*belg*) rainfall with tentative evidence of increased and extended (later cessation) long season rainfall (*kiremt*)
Oromia South	Hotter – with more rapid increases in later part of *belg* (March-May) (0.6°C/decade) – but significant increases in the *kiremt* (June-September) (+0.4-0.6°C/decade)	• A mixed but tentative signal of drying (east) and increased rainfall (west) during the March-May seasonal rainfall, but a stronger message of increased rainfall and intensity during the October-December seasonal rainfall.
Afar	Higher temperatures during rainy season 0.4-0.6°C/decade Higher temperatures and more rapid temperature increases during dry period (March-May) (> 0.6°C/decade).	• Intensification of drier conditions for the first rainfall season (March-May) • Intensification of wet events during *kiremt* (June-September)

REGION	TEMPERATURE TRENDS (1981-2014)	RAINFALL TRENDS (1981-2015)
		• Tentative evidence of decreasing and more erratic short season (*belg*) rainfall with tentative evidence of increased and extended (later cessation) long season rainfall (*kiremt*)
Tigray	Decreasing maximum temperatures during dry period (June-September) Hotter temperatures during October-December	• A tentative message of increased rainfall during the main rainy season and a possible extension of the season (later cessation) with very tentative evidence of increased rainfall intensity and frequency of heavy rainfall events

Despite the fact that most subsistence agriculture in the areas of Ethiopia examined by ATLAS rely on rainfall rather than irrigation systems, improved farm management practices, improved seeds and appropriate use of pesticides and fertilizers have played a significant role in increasing observed yields. Therefore, investigating the relative importance of non-climatic factors on crop yields may shed light on where appropriate interventions to adapt to climate change and counter its negative effects on future crop yields could be made. In the following section, some specific adaptation responses are discussed.

ADAPTATION RESPONSES

There is a tendency in the development assistance community to consider mainstreaming climate change an “additional” burden on project implementation that threatens already limited budgets. It is true that in many cases, this process may bring additional costs and require modifications. It is important, however, to recognize that the process through which climate change risk is considered, may in fact not only **safeguard the sustainability of development objectives**, but also bring flexibility to the project, allowing for adjustments to interventions to take place under an inevitably changing climate which could, in fact, increase the vulnerability of target populations.

Climate variability and extreme events (rainfall variability, droughts, floods, etc.) are already impacting the health, life and livelihoods of Ethiopia’s population, whose reliance on resource dependent activities makes them more vulnerable. Current trends, coupled with projected changes in climate for the coming decades could have serious repercussions for both people and the ecosystems on which they depend by adversely impacting:

- Food production
- Food access
- Energy security and the availability of fuel wood

The differential impacts and opportunities brought about by climate change result from a variety of interconnected factors contributing to vulnerability and not limited to the health of the underlying natural resource base, including socio-economic conditions and advances in relevant technology (e.g. agriculture). Given the differential impacts and underlying capacity of communities, **there is no one-size-fits-all approach to integrating climate change adaptation activities** across FFP areas. An analysis of the likely consequences to development sectors such as food production and water availability is complex as it involves food and its production, trade, nutrition and other aspects as well as how people access and secure food. Effective adaptation planning and implementation require sound risk assessments that identify the specific impacts to food security that may be induced or exacerbated by increased climate variability. This allows for responses to be prioritized and compared objectively to other risks based on resource availability and cost.

The insights from the field visits and literature review illustrate the need to consider this a cross-cutting issue that may not only require adjustments and changes to proposed interventions but also help to promote more flexible investment designs – ones that are sustainable and resilient over the life of the project and which can address a multitude of stressors of which climate is just one. Addressing the impacts from current variability, known as the “adaptation deficit” is an important first step in safeguarding against an uncertain future, and includes continued investment in:

- Watershed management and rangeland rehabilitation

- Livelihood diversification
- Outreach and building capacity on appropriate farm technologies and practices, including green manure/cover crops, improved seed varieties and other innovation on-farm management practices

Many implementing partners are already climate-proofing their activities and these lessons should be scaled up. Economic growth, poverty and poverty reduction are closely related to climate. To a significant degree the food insecure, dependent on agriculture and livestock, are dependent on weather patterns for their livelihoods and prosperity. Ethiopia's Climate Resilient Green Economy Strategy (Federal Democratic Republic of Ethiopia, 2011) recognizes this and aims to help the country realize its ambition of reaching middle-income status before 2025 by outlining several priorities to address the adverse effects of climate change through a green economy pathway. It recognizes water, soil, land and forests as the foundations for the country's economic development, food security and livelihoods and highlights two pillars of specific import to food security:

- Agriculture: improving crop and livestock production practices for food security and farmer income through intensification and restoration of degraded lands
- Forestry and ecosystem management: protecting and reestablishing forests for their economic and ecosystem services, which recognizes the role of natural resources and assets as buffers against a more variable climate

Furthermore, the experiences in the intervention regions to date suggest that to capitalize on the experiences gained by projects already in place, it is important to jointly address the following challenges:

- The urgency of promoting the exchange of knowledge and experience to support adaptation as a process of "learning by doing" rather than as an end point.
- The need to scale up investments in climate-smart agriculture and improved technologies to safeguard populations against climate risks.
- The imperative to diversify/spread the risk rather than promoting single-solution approaches that remain vulnerable to climate shocks.

Recommendations to address these challenges are discussed below.

LEARNING BY DOING

Adaptation to climate change involves making adjustments in response to actual or expected changes in climate to reduce adverse impacts or to take advantage of opportunities. Testing, learning and building adaptive capacity for climate change adaptation is about adding a new layer to existing best practice in development. In this light, several activities could promote a learning-by-doing approach to climate adaptation in FFP programming in Ethiopia:

Build on the adaptation strategies outlined in the draft Ministry of Agriculture Climate Resilient Green Economy (CRGE) strategy. Important examples of investments exist today that could provide a starting point for program design, and which are supported through the

CRGE, Productive Safety Net Programme (PSNP), USAID/Feed the Future and others in order to increase the resilience of the region's food insecure to climate variability and change. The Climate Smart Initiative (CSI) is piloting a number of activities to determine how to better integrate PSNP and the Household Asset Building Program to facilitate climate change mainstreaming. A final CSI project report is due later this year, and FFP can benefit from lessons learned from the pilots to prioritize future mainstreaming activities. An emphasis on natural resource management, including restoration of degraded farmlands through improved conservation agriculture practices and integrated watershed management all offer important activities that could be scaled-up and promoted. The examples below illustrate where they have helped strengthen practices that increase the supply of food in the region and in turn help restore soils and protect limited water sources.

Explicitly consider the climate variability of the region in risk management investments. Farmers and pastoralists in the DFAP intervention areas have always faced weather variability and other constraints that create production uncertainties, and they routinely make decisions about ways to hedge these risks. However, this is most often an informal process with variable consequences. Evidence-based strategies can promote more secure risk management. Although there are a few current DFAP projects that aim to develop evidence-based risk management tools, they lack explicit consideration of climate change. FFP could leverage these activities to demonstrate the value of incorporating climate change in risk management.

Many implementing partners are already climate-proofing their activities and these lessons should be scaled up. Some examples are listed in Table 6.

Table 6: Illustrative agriculture sector interventions and climate vulnerability responses

PROJECT ACTIVITY/STRATEGY	CLIMATE CHANGE CONSIDERATIONS
Cultivate high value crops	Select drought resistant varieties in areas where drought is increasing
Seedling nurseries to supply plants to restore deforested watersheds.	Prioritize species less susceptible to drought. Include nitrogen-fixing species that can help restore degraded soils.
Use of productivity-enhancing inputs such as fertilizer and improved seeds.	Determine best investments based on projected climate changes in different agro-ecological zones.
Soil and water conservation measures to restore watersheds and reduce erosion	Standardize and prioritize interventions based on projected changes in rainfall intensity and suitability for local conditions (based on slopes, soil types, etc.) and projected climate change.
Water harvesting	Design interventions strategically, based on expected changes in seasonal flows. For example, if climate information suggests potential floods in the October-December period, and significant decrease in rainfall for the March-September period, consider a strategy of moisture harvesting and storage, using both traditional and improved technologies, during the October-December period (floods from the short rains) for use during the March-September period.

Promote appropriate seed use (short maturing and drought tolerant). More erratic rainfall patterns point to the need to promote appropriate relevant seed selection in order to minimize the loss of production and allow at least a small harvest to the food insecure. In Oromia, the Graduation with Resilience to Achieve Sustainable Development (GRAD) project is promoting early maturing, short-season and/or drought resistant crop and forage varieties of potatoes, haricot beans, gudane, nasir, dame and kale. The relatively high adoption rates at Village Economic and Social Association and household levels (early maturing – 69%, drought tolerant – 51%) and early positive results of applying these practices suggest they could be scaled up in other food insecure regions to promote productivity.

SCALING UP CLIMATE-SMART AGRICULTURE INVESTMENTS

Conservation and restoration practices offer long-term solutions to climate risks. The PSNP and CRGE both suggest that agriculture intensification and expansion should be promoted, including learning from existing experiences in:

- Scaling up climate-smart agricultural practices that improve soil moisture content to reduce vulnerability to erratic rainfall
- Restoration of degraded agricultural lands through small-, medium- and large-scale irrigation, water storage infrastructure and capacity building for water-efficient cropping practices in order to guarantee year-round sources of water for crop production, and reduces dry period shocks. Examples include furrow irrigation, canals, use of rope and washer pumps, hand-dug wells, motor pumping from rivers, as well as integrated watershed management plans that promote reforestation of critical upper catchments and help reduce erosion during periods of floods. For example, the rehabilitation investments aimed at improving the sustainability of local livelihoods of the Managing Environmental Resources to Enable Transitions (MERET) project suggested food insecurity in target areas was reduced by 40%. In Raya Azebo, the Relief Society of Tigray built conveyance structures and encouraged contour plowing to form furrows and ridges to maximize capture of moisture. In addition, hillside terraces, bunds, and small check dams in the upper catchment help slow rapid runoff and prevent erosion. Hillside terraces trap sediments, helping to build-up a layer of nutrient-rich soil, providing additional cultivation areas.

DIVERSIFYING RISK

It is important to note that many of the adaptation options that emerge above will appear familiar. They will tend to be of the type that would have been good things to do anyhow. The essential distinction is not that the options suggest doing different things but that they suggest doing things differently—with more flexibility in design and implementation to better manage uncertainty. In short, they support engagement in "adaptive adaptation."

In practical terms, many entry points for incorporating a climate lens exist at all levels of activities, including those implemented at the:

- Field level: protecting existing livelihood systems, diversifying existing sources of income, changing livelihood strategies to include non-traditional income generation opportunities where practical, awareness raising on climate change adaptation issues and providing an enabling environment for planned migration, when all other options are impossible

- Project level: effective use of crop resources, promotion of integrated or conservation farming systems, research and dissemination of crop varieties and breeds adapted to changing climatic conditions, improved infrastructure for small scale water capture, storage and use, and improved soil management practices

Clearly, social protection and safety net programs such as the PSNP offer critical platforms and vehicles for investing in risk management. But as the analysis above indicates business as usual is not an option. The changing climate and its impacts on food security will require concerted action to better manage climate risks. This offers a window of opportunity to integrate climate risk management into the broader food security development pathways, including to:

- **Develop locally and seasonally relevant investments, standardizing and prioritizing interventions based on local situations.** There is increasing recognition of the need for local vulnerability assessments. The World Bank (2011), for example, has concluded that "a better understanding of the local dimensions of vulnerability is essential to developing appropriate adaptation measures," and notes a particular need for detailed vulnerability assessments in arid, semi-arid, and dry sub-humid lowland communities. Activities that capitalize on and address, at disaggregated seasonal scales the opportunities and constraints posed by a changing climate should be promoted. For example, the October-December floods occur during the harvest season while rainfall decreases (March-September) correspond to the planting and development seasons. A two-pronged strategy that recognizes and capitalizes on these dynamics would encourage moisture harvesting and storage using both traditional and improved technologies during the short rains (floods) complimented with water conservation and irrigation investments during the long rains. Adaption strategies should seek a cost-effective balance of information, institutional and investment options. Vulnerability is a function of not only the climate regime but also the existing coping capacity of people, institutions and infrastructure. Hence it is necessary to consider a mix of social, economic, institutional strengthening, capacity building and technical or investment options to reach cost-effective strategy to address the vulnerability and risk management problem.

- **Support generation of local climate information collection.** As the field findings indicate, food security is closely tied to changing climatic conditions. Yet there is limited locally-relevant information to help understand the potential effects of climate change on food-system components. Available climate analyses are at regional or national scales, and seldom provide information to support local decision-making. Locally-relevant climate information would add significant value to project design and implementation. For example, Table 7 indicates some of the critical farming activities influenced by local climatic conditions, and provides examples of the kind of information farmers could use to improve their decisions. Matrices like this one provide a window of opportunity to collectively plan for adaptation.

Table 7: Examples of analyses to support local investment decisions

FARMER QUESTIONS/CONCERNS		CLIMATE ANALYSIS	AVAILABLE DATA/INDICATORS
Climate-Related Risks	**Timing of Critical Activities Relative to Risks**		
What are climate-related risks to crop and pasture production in terms of: • air temperature, • soil moisture • water availability (e.g., runoff, groundwater sources, irrigation schemes)	What are optimal times for planting and harvest given anticipated seasonal, inter-annual and longer-term climate variability/change? What are best seed varieties given these considerations? What is best time for fertilizer use and other inputs?	Seasonal rainfall patterns	Normalized Difference Vegetation Index
		Trends	Daily, monthly; seasonal/annual rainfall and temperature averages
		Rainfall variation	Coefficient of variation (CV) of annual/seasonal rainfall T-max, T-min, daily rainfall, etc.
		Drought Frequency	Standardized Rainfall Anomaly Palmer Drought Severity Index

- **Consider carrying capacity in programming decisions.** Climate change will place additional, unprecedented stresses on communities in the DFAP intervention areas. Even in the best circumstances, individuals with relatively high adaptive capacity and flexible response strategies may find it difficult to adjust to increased climatic extremes or variation outside of historical experience. Adaptation challenges will be even greater for individuals experiencing persistent, severe poverty. Households that are barely making enough to survive – who are “living on the edge” – are often “running just to stay in place.” A community with a high degree of poverty and food insecurity, that is located in an area of widespread and intractable environmental degradation, increasing population pressure and a lack of water resources, may have reached its “carrying capacity,” and therefore retain little or no ability to adjust to increasingly challenging conditions. Individuals and households in these situations may be unable to benefit from traditional food security strategies – especially with climate change an additional layer of stress. It therefore makes sense to consider aggressive introduction and scaling of interventions that expand income generation opportunities beyond the bounds of traditional livelihood strategies which rely on a limited natural resource base.

- **Explore alternative responses to reduce land degradation and improve productivity of natural resources in support of agriculture and food security**. For example, they offer the opportunity to explore the potential to introduce Payment for Ecosystem Services (PES) as a way of securing the buffer protection catchments and certain ecosystems provide against a more erratic climate. Land availability is a universal constraint to farmers and pastoralists communities in Ethiopia. While the food insecure living in upper reaches of important watersheds face pressures similar to others as they struggle to guarantee their subsistence in increasingly erratic climate and market conditions, they also play a pivotal role as the custodians of critical water sources that both harm and benefit many downstream. Several examples are available for PES schemes under conditions of degradation, land scarcity and disappearing natural resources limiting livelihood options in Africa, Latin America and Asia, show the value of payments as a way of promoting agricultural practices aimed at controlling runoff and soil erosion, while improving crop production (e.g. in the Ruvu watershed of the Uluguru mountains in Tanzania, where crop production improved by 60% in four years). The underlying premise under a climate risk management perspective is that they can: inspire incentives for ecosystem restoration and improved natural resource management and contribute to capacity building and vulnerability reduction by increasing the buffering capacity of socio-ecological systems against a highly variable climate. These schemes provide a window of opportunity towards effecting long-term behavior change which could lessen pressures on limited resources and increase their productivity by creating economic incentives for improved environmental management. A variety of payment standards have been applied in existing pilots (many of which are showcased in PRESA (Pro-poor Rewards for Environmental Services in Africa http://presa.worldagroforestry.org/) , including cash transfers, improvements in public services such as health or education facilities, local infrastructure improvements (e.g. roads), and improvements to land tenure rights.

- **Address the long term institutional development and reform processes that are essential for adaptation.** Development experience suggests that capacity building, institutional strengthening, and in some cases major reforms (or support for new government initiated policy reforms) at the national, local government, community and farm level are critical. In the case of adaptation to climate vulnerability this is doubly so. The uncertainty concerning the magnitude of climate change and when significant effects can be expected offers an opportunity in this regard. Capacity building, institutional strengthening and reform are long term processes whose major impacts on livelihood performance, poverty and growth can often require decades to fully achieve the intended outcomes in terms of scope and breadth of impact. Current climate variability as it impacts, for example on agricultural systems and farmers, is an immediate problem to be addressed, but longer term effects of climate change will emerge gradually affording an opportunity to concentrate on awareness, capacity building, testing and introducing adaptation options (agricultural research, advisory services, monitoring and planning). The critical issue in this regard for the present is to identify knowledge and capacity gaps so that these gaps are filled in time to avoid adverse impacts.

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