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UGANDA CLIMATE CHANGE VULNERABILITY ASSESSMENT REPORT

August, 2013

ARCC

African and Latin American Resilience to Climate Change Project

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ACRONYMS

ARCC	African and Latin American Resilience to Climate Change
ARU	Arua
BUT	Butiaba
CBO	Community-Based Organization
CCU	Climate Change Unit
CO_2	Carbon Dioxide
DJF	December, January, February
DOM	Uganda Department of Meteorology
DSIP	Agriculture Sector Development Strategy and Investment Plan
ENSO	El Niño Southern Oscillation
ENT	Entebbe
FAO	Food and Agriculture Organization of the United Nations
FCS	Food Consumption Score
FGD	Focus Group Discussion
GCM	General Circulation Model
GHG	Greenhouse Gas
GoU	Government of Uganda
GUL	Gulu
HH	Households
HIV/AIDS	Human Immunodeficiency Virus/Auto-Immune Deficiency Syndrome
HLT	Household Livelihood Type
ICTA	International Center for Tropical Agriculture
IITA	International Institute for Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
JIN	Jinja
JJA	June, July, August
KAB	Kabale
KAS	Kasese
KII	Key Informant Interview
KIT	Kitgum
KOT	Kotido
M&E	Monitoring and Evaluation
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MAM	March, April, May
MAS	Masindi
MBA	Mbarara
MoH	Ministry of Health
MUB	Mubende
MWE	Ministry of Water and Environment
NAADS	National Agricultural Advisory Services

NAM	Namulonge
NARO	National Agricultural Research Organization
NCG	Nordic Consulting Group
NGO	Nongovernmental Organization
NRM	Natural Resource Management
PCA	Principal Component Analysis
RCP	Representative Concentration Pathways
SIP	Sipi
SON	September, October, November
SOR	Soroti
SST	Sea-Surface Temperatures
T-min	Minimum temperature
T-max	Maximum temperature
TOR	Tororo
UDHS	Uganda Demographic Health Survey
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VA	Vulnerability Assessment
VSLA	Village Savings and Loans Associations

EXECUTIVE SUMMARY

BACKGROUND

During the coming decades Uganda's agricultural households will continue to face significant challenges, including a deteriorating natural resource base and eroding ecosystem services, and reduced access to land due to a rapidly rising population – in addition to the ongoing threats of conflict and economic crisis. While fully recognizing the importance of all of these factors, this assessment focuses on the additional pressure that Uganda's agricultural households will face as a result of current and potential future impacts of climate change.

The U.S. Agency for International Development (USAID)/African and Latin American Resilience to Climate Change (ARCC) Project conducted the Uganda Climate Change Vulnerability Assessment in 2012. Field research focused on Gulu, Lira, Luweero, Mbale, Isingiro, and Kasese – six USAID/Feed the Future priority districts that include important cropping systems, represent different agro-ecological zones, and are near weather stations that have collected consistent rainfall and temperature data.

The study employed a mixed-method approach that included historical climate analysis and projections; a value chain analysis of eight key crops and a phenological review (i.e., how climate change affects the growth cycle of each of those crops); a livelihood survey of 800 households; 80 focus group discussions; key informant interviews with representatives from district and national levels; and a desktop assessment of water use for agriculture.

This research and analysis show how current climate patterns shape—and how future climate patterns may influence—key crop value chains and the livelihoods of households that depend on them. Along with the results of this assessment, this report includes recommendations enriched by options generated by key stakeholders from government, donor agencies, research organizations, and civil society during a participatory multi-stakeholder options analysis meeting that took place in Uganda on January 31, 2013.

KEY FINDINGS

Climate: Uganda lies within a relatively humid equatorial climate zone, and the topography, prevailing winds, and lakes and rivers cause large differences in rainfall patterns across the country. Changes in sea surface temperatures in the distant tropical Pacific, Indian and, to a lesser extent, Atlantic Oceans strongly influence annual rainfall amounts and timing. Key findings include the following:

Rainfall:

- Current and past trends indicate that the timing of rainfall can vary considerably; the onset of rainy seasons can shift by 15 to 30 days (earlier or later), while the length of the rainy season can change by 20 to 40 days from year to year.
- No significant change in average annual rainfall could be detected in the 60-year historical record.
- Similarly, no significant change in average annual rainfall is projected for the 2015-2045 period.

- The most consistent finding was the projection of an increase in rainfall in December, January, and February, which is typically a dry season in all locations. This increase could have strong impacts on agriculture, especially with respect to tree crops (e.g., coffee) and post-harvest activities such as drying and storage.
- There is a potential for an increase in the frequency of extreme events (e.g., heavy rainstorms, flooding, etc.)

Temperature:

- An analysis of average annual temperatures between 1951-1980 and 1981-2010, shows a notable increase of approximately 0.5-1.2 °C for minimum temperatures and 0.6-0.9 °C for maximum temperatures.
- This warming trend is projected to continue, with some models projecting an increase of more than 2 °C by 2030. It will likely have a strong impact on agriculture and livestock, increasing the risk of disease and pest infestations.

Crop value chain analysis and phenological review: The crops considered in this assessment are those most widely grown in Uganda, and many are vulnerable to the projected rising temperatures and increasing dry season rainfall. Of the crops analyzed in this assessment, Arabica coffee is the most vulnerable, while cassava is the least. Overall, from most to least sensitive crops, they are: Arabica Coffee, robusta coffee, rice, maize, East African Highland Banana (matooke), beans, sorghum, sweet potatoes, and cassava. Other key findings follow:

- **Coffee:** Rising temperatures and erratic rainfall increase the risk of disease and pest infestations in coffee.
- **Rice:** Two major rice diseases (blast and bacterial leaf blight) affect rice yields and are significantly aggravated by weather conditions such as higher temperatures, air humidity, or soil moisture.
- **Maize:** Aflatoxin contamination represents a serious threat to the marketing of maize and will likely worsen if dry season rainfall increases.
- **East African Highland Banana (matooke):** While matooke is less vulnerable to increasing temperatures than coffee is, the potential impact of pests and diseases on the crop is significant.
- **Beans:** Beans are vulnerable to fungal and viral diseases when excessive rain falls during critical growing periods.
- **Multiple Grains:** Erratic rain could increase post-harvest storage losses of crops typically dried in the sun (e.g., maize, beans, coffee, rice, etc.), due to increased pests and rotting.
- **Sorghum:** Coupled with irregular precipitation, increased temperatures could result in the proliferation of striga, a parasitic weed that affects sorghum and is prevalent in areas with degraded soils.
- **Sweet potatoes and cassava**: Both crops grow well at temperatures much higher than current ones, but are also vulnerable to pests and disease.

Household Vulnerability: None of the households studied have significant buffers against additional stress. Village focus group results indicate that they all face important challenges indirectly related to climate, such as declining soil fertility and increasing land pressure. Households reported, on average, being food insecure for almost three months in 2011. Specific attributes make some households more sensitive to climate variability and change. More vulnerable households are those with many of the following characteristics:

- Lower proportion of able-bodied (working) members;
- Less well educated;
- More likely to be headed by females;
- Less likely to sell a portion of their crops or livestock;
- Less access to loans;
- Participate less frequently in community groups such as producer associations, cultural or labor savings groups, and religious organizations; and
- Earn income less frequently from off-farm sources (and when they do, that income is less than the amount that more secure households earn).

The systemic vulnerability of households studied also stems from the fact that they depend heavily on crops whose value chains are sensitive to climate variability and change; any change in food production critically increases overall vulnerability. For example, maize is an essential part of the diet of the most vulnerable households, and they sell a small portion of their harvest; yet this small amount of maize they sell represents a significant source of cash for the household. Less vulnerable households plant maize more often, sell a greater portion of their harvest, and have other more important sources of income. Similarly, the most vulnerable households in coffee-growing districts sell coffee less often, but they rely more heavily on it for income.

Adaptive Capacity: The level of income diversity affects the ability of households to adapt to climate change. The assessment concludes that households with greater adaptive capacity manage more diverse agricultural portfolios; they plant more crops and invest in livestock. They also have a more varied mix of on-farm and off-farm income sources. Marked differences by districts significantly affect this diversity. Access to land plays a strong role in on-farm diversification; as a result, land pressure in more densely populated districts such as Mbale increases vulnerability. Proximity to urban centers also increases off-farm income and thus significantly reduces vulnerability to climate variability and change.

The assessment identified a wide range of measures that households employ to adapt to climate variability and change. They modify their management practices by shifting planting dates, preparing soil differently, or changing the mix of crops farmed on the same plot. Households also address risks by planting additional crops and crop varieties, and by investing in livestock or fruit trees. Additionally, households seek sources of income outside of agriculture, both through short-term ‘coping’ strategies, such as hiring themselves out as manual labor or by producing charcoal; and through longer-term strategies, such as migration and investments in the education of their children.

CONCLUSIONS AND RECOMMENDATIONS

Adaptive strategies developed at national scales might not be locally appropriate, particularly when climate impacts and adaptation responses are local (i.e., influenced by ecosystems and social and cultural relations unique to the area). National programs that are not complemented by locally relevant and tested adaptive strategies are unlikely to produce useful strategies for most farming communities. On the other hand, this assessment reiterates that while adaptation occurs farm by farm, the identification and dissemination of adaptation options—and enabling of their adoption—requires a national effort.

Similarly, with regard to time horizons, although some adaptations and adaptation policies are short term and require more immediate action, other policies and practices will yield adaptive benefits over the long run. These geographic and time-scale considerations led the assessment team to identify specific recommendations summarized below according to activity focus: a) establishing the national context for adaptive agriculture; b) expanding research and learning across stakeholder groups; and c) strengthening and diversifying livelihoods. Please see the full report for a detailed list of recommendations.

NATIONAL CONTEXT FOR ADAPTIVE AGRICULTURE

This set of recommendations refers to establishing policies and investment strategies that address large-scale, long-term threats to value chains, livelihoods, and agricultural institutions. It includes recommendations that facilitate local adaptation over shorter time periods, with an emphasis on improving the content and pathways for communicating information between researchers, scientists, and farmers. Primary recommendations follow:

1. Build the capacity of the Uganda Department of Meteorology (DOM); Climate Change Unit (CCU); and Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF) to **improve the production, distribution, and use of climate information that responds to the needs of decision makers, as well as those of farmers and other stakeholders.**
    - Provide necessary technical and financial support to the DOM and CCU for the development of the national climate datasets and information.
    - Build capacity of Ugandan institutions to develop and routinely use downscaled climate projections.
    - Develop a platform/mechanism for results (current trends and projections) to be shared at regional, national, district, and local levels.
2. Assist the Government of Uganda to **organize and develop a high-level, multi-sectoral body to support the CCU to strengthen the climate change agenda and guide policy** development.
    - Create a multi-sectoral coordinating committee, led by the CCU, to regularly meet and plan cross-sector coordination and strategic investment regarding long-term climate change impacts.
    - Mainstream a climate change perspective into the programming of agricultural and natural resource management services.

RESEARCH AND OUTREACH AT THE NATIONAL, DISTRICT, AND COMMUNITY LEVELS

This set of recommendations refers to how knowledge and information related to climate change adaptation is generated and shared. Consistent with the framework, recommendations encourage the decentralization and democratization of innovation and planning, while also improving the exchange of information among all actors concerned with adaptation, and quickening the pace at which they learn from each other:

1. **Develop a wide range of high-yielding and climate appropriate crop varieties, farm management strategies (focused on diversification and intensification of farming), and post-harvest storage strategies from which farmers can choose**. Ideally, multi-stakeholder dialogues and platforms, similar to the one recommended above, shape the evolution of the choices

generated with and for farmers. Adaptive choices should meet the locally specific challenges of the following items:

- A gradual increase in temperature is the top priority given the certainty of the outcome and its likely impact on key crops. Therefore, we recommend:
  - investment in varieties of maize and beans that resist rising temperatures (and continue to meet local preferences);
  - investment in shading and other temperature-reducing management techniques, a top priority for coffee and matooke; and
  - improvements in soil moisture management to offset expected increases in evapotranspiration.
- Changing rainfall patterns and intensities affect soil moisture, crop growth at different stages, post-harvest storage conditions, and especially increases in "dry season" rainfall. Therefore, we recommend:
  - development and promotion of pest-/disease-resistant varieties in all districts, with an emphasis on pests and diseases that thrive in moist environments;
  - promotion of improved soil management (moisture and fertility) techniques;
  - prevention of disease and pests associated with increasing temperatures and variable rainfall by maintaining reserves of protected or treated seeds and plants that are disease- and pest-free at district research centers, which improves recovery after disease outbreaks and protects planting material for the next season; and
  - development of management strategies that reduce pest and disease risk (i.e., improve storage facilities).
- Many agro-ecosystem services, such as the provision of clean water, creation of fertile soil, and maintenance of micro-climates/habitats, are deteriorating. Therefore, we recommend:
  - a clearer definition of challenges and needs in each district based on local conditions in order to develop appropriate research agendas, and
  - promotion of synergy between formal agricultural research with farmer-led innovation.

2. **Strengthen the capacity of farmer groups to experiment with new ideas and to adapt them to local environmental and social conditions.** Promote active participation and leadership by women and men, old and young, and poor and "better-off" to assure the best mix of adaptive innovations. Pilot programs for farmer experimentation and innovation can be undertaken where local social capital is strong but overall vulnerability is high. These programs can provide lessons for setting up innovation systems elsewhere.
3. **Strengthen the capacity of farmer organizations to link laterally (amongst themselves) and vertically (with other research institutions at district and national levels)** to scale up the dissemination of successful innovations and adaptations.

LIVELIHOOD STRENGTHENING AND DIVERSIFICATION

This set of recommendations addresses the need to develop and diversify livelihood assets as a strategy for reducing household sensitivity to crop-related stresses. The goal is to build on existing livelihoods strengthening programs and improve the capacity of farmers to strengthen and diversify their livelihoods. Primary recommendations for strengthening livelihoods and diversification follow:

1. **Provide opportunities to spread financial risk in agriculture to allow for greater innovation and adaptation**. This includes financial instruments, such as strengthening loan and insurance programs, and strengthening farmer organizations and their links to markets.

2. **Strengthen assets to encourage innovation, diversify livelihoods, and improve adaptive capacity**. Assets are a key variable that distinguishes most vulnerable from least vulnerable households. Investing in asset growth for the most at-risk will greatly reduce their vulnerability. Some of the most important assets noted in the vulnerability assessment follow:

    - *Financial assets*. Expand savings and loan programs, micro-grants for tree planting, or livestock purchasing programs.
    - *Human capital*. Expand training and technical backstopping to encourage local investments in agricultural processing and marketing, particularly in areas where human capital is weak and where off-farm opportunities are weak.
    - *Social capital*. Promote and strengthen community-based organizations—farmers' associations and self-help and watershed management groups—and contract farming with preferred consumers in areas where social capital may be significant, but where links to climate change-related issues are weak.

3. For Government of Uganda ministries (Finance, Planning and Economic Development, Trade, Industry & Cooperatives, Local Government, and Education), nongovernmental organizations, community-based organizations, and the private sector, to **invest in less climate-dependent livelihoods**. Investments should target locations where agriculture-based livelihoods are under the most pressure from climate change and other environmental and social developments. Target areas should also consider, however, whether or not non-agricultural livelihoods are promising. Specific recommendations follow:

    - Promote agricultural processing.
    - Develop apprenticeship programs for youth.
    - Support functional numeracy and literacy training along with basic business skills training where there are opportunities for commercial activities.
    - Support programs that improve school assistance and retention rates, particularly for girls.

1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 PURPOSE AND APPROACH

The U.S. Agency for International Development (USAID)/Support for African and Latin American Resilience to Climate Change (ARCC) conducted the Uganda Climate Change Vulnerability Assessment (Uganda VA) in 2012 in response to requests from the USAID/Africa Bureau and USAID/Uganda. The purpose of the assessment is to improve understanding of the impact of climate change on rural livelihoods in Uganda to inform food security and agricultural programming and investment decisions by focusing on select crop value chains.

This assessment represents a multidisciplinary effort to document the complicated impact of climate-related environmental change on Ugandan agricultural crops and the households that grow them. Research focused on Gulu, Lira, Luweero, Mbale, Isingiro, and Kasese – six USAID/Feed the Future priority districts that include important crops (beans, cassava, coffee (Arabica and Robusta), maize, East African Highland Banana (matooke), rice, and sorghum), represent different agro-ecological zones, and are near weather stations that have collected consistent rainfall and temperature data. This assessment has integrated climate data, projections of climate change, phenological characteristics of key crops, value chain linkages, and household livelihood patterns in a comprehensive fashion to construct an overall analysis of the sector's vulnerability to climate variation and change within the context of the daily lives of rural Ugandans.

The key focus of this assessment asks how projected changes in climate will affect important agricultural value chains within Uganda, which in turn affect the livelihoods that rely upon these value chains. From this livelihood perspective, the assessment also identifies the key adaptation strategies that farmers have engaged in to adjust to climate change pressures. These adaptive "pathways" are designed to inform the investment strategies of the Government of Uganda (GoU), USAID/Uganda, and the donor community as national and local adaptation plans are prepared and implemented.

Along with the results of this assessment, this report includes recommendations enriched by options generated by key stakeholders from government, donor agencies, research organizations, and civil society during a participatory multi-stakeholder options analysis meeting, which took place in Uganda on January 31, 2013. At the workshop, decision makers and leaders learned about the results of the Uganda VA and became familiar with several climate scenarios developed from the data presented in this assessment. Based on an enhanced understanding of the coming challenges posed by climate change—including future implications, constraints, and opportunities for addressing climate change—participants validated and/or improved on draft options and contributed additional recommendations.

This report is organized into three sections, beginning with an introduction that presents the conceptual research framework, the overall approach, background on local context, and an overview of the methodology. The second section presents the integrated assessment findings organized according to key components of vulnerability: climate change exposure, sensitivity of the selected crop value chains and households to climate change, and the adaptive capacity to respond to the anticipated impact of climate change. The last section presents recommendations/options based on the resulting understanding of exposure, sensitivity, and adaptive capacity.

The overall Uganda VA approach includes six steps: (1) a desk review of all relevant literature, (2) a scoping visit, (3) a field assessment phase, (4) data compilation and analysis, (5) the presentation of results, and (6) a participatory analysis and definition of climate adaptation options.

At the beginning of the Uganda VA process, the literature review and scoping visit formed the basis for the assessment design and contributed valuable secondary data. The desk review phase was ongoing even as subsequent meetings and visits identified new sources of information. In April 2012, a multidisciplinary scoping team visited Uganda to conduct a series of semi-structured key informant interviews with a representative group of stakeholders (individuals and institutions) engaged in climate change. Their goal was to inform the design of the VA, map institutions, and identify relevant information sources and potential assessment partners. During the scoping visit, the team also met with USAID personnel to discuss and agree on the scope of work for the Uganda VA.

Four primary information gaps were identified during the visit: (1) practical information related to climate change, (2) a clear understanding of climate change, (3) empirical information concerning the impact of climate change on agriculture, and 4) the need to understand the impact of climate change throughout the entire value chain system. Implementation and political gaps were also identified, including a need for additional analyses of adaptive strategies, translation of policies into real action on the ground and improved coordination with respect to climate change. Shortly following the scoping visit, the VA team defined the research framework and assessment methodology based on the needs and gaps identified during the visit. An overview of the methodology is presented in detail in Section 1.2 (page 14).

1.1.2 GENERAL CONTEXT

Uganda is located on the East African plateau and lies almost completely within the Nile basin. Although situated close to the equator, it has diverse climate patterns due to the country's unique bio-physical characteristics influenced by several large rivers, bodies of water, and mountain ranges to the east and west. Rainfall varies throughout the country: from rain spread throughout the year in the south, with heavy rains in the Rwenzori mountainous region in the southwest and rains falling from March to June and November/December near Entebbe on the northern shore of Lake Victoria. In the north, a dry season emerges from November to February in Gulu; the northeastern Karamoja region has the driest climate and is most susceptible to drought.

Influenced by these bio-physical and climate variations, growing conditions also vary throughout the country. Summaries of the agro-ecological conditions of the assessment's six focus districts follow:

- **Gulu and Lira** are characterized by northwestern savannah and grasslands with agro-ecological conditions for mixed agriculture, annual crops, oilseed production, tobacco and cotton cash crops, and livestock. The GoU's Agriculture Sector Development Strategy and Investment Plan (DSIP) priority crops for the zone are coffee—primarily Robusta coffee—and beans.
- **Isingiro** is characterized by southwestern farmlands with agro-ecological conditions for Robusta coffee, and matooke supplemented with annuals and root crops. DSIP priority crops for the zone are Robusta and Arabica coffee, tea, and matooke.

- **Luweero** is characterized by Kyoga plains with agro-ecological conditions favoring cereals and root crops cultivation—particularly sweet potatoes, cassava, millet/sorghum, maize, groundnuts, beans, and cowpeas. DSIP priority production for the zone includes maize, cassava, poultry, and fisheries.
- **Mbale and Kasese** are characterized by highlands ranging from 1,500 to 1,750 meters with agro-ecological conditions suited to growing matooke, Arabica coffee, Irish potatoes, maize, wheat, and tea. Land holdings are small with high population densities. DSIP priority production for the zone includes coffee, maize, tea, and dairy.

To put the assessment within context, it is important to understand significant non-climate stressors that make rural Ugandan households (approximately 85 percent of the population [GoU, UBOS, 2012]) vulnerable to climate change, including national indicators of well-being, population, and land pressure trends. Uganda continues to be one of the poorest nations in the world, with 24.5 percent of the population living on less than $1.25 a day (World Bank, n.d.; MoFPED, 2012). Poverty fell between 2005-2006 and 2009-2010 from 31.1 percent to 24.5 percent of the national population, i.e., from 8.5 million to 7.5 million people. Social indicators for health reflect how the country continues to struggle in addressing poverty. According to the 2002 census, life expectancy was estimated to be 50.4 years (GoU, UBOS, 2012); the infant mortality rate was approximately 54 deaths per 1,000 live births (according to the 2011 Uganda Demographic Health Survey (UBOS), and 352 women die per 100,000 births (GoU, UBOS Ministry of Health [MoH], 2011).

In mid-2012 the population of Uganda was estimated to be 34.1 million (GoU, UBOS, 2012) with one of the highest annual population growth rates in the world at 3.2 percent, with an increasing trend. It also has the second highest total fertility rate in the world, with 6.2 in 2011 (GoU, UBOS Ministry of Health [MoH], 2011) children born per woman. The population is young, with a median age of 15 years (CIA, 2009). The number of internally displaced persons has changed over the last five years, with the majority having returned home and approximately 30,000 remaining in displacement camps as of January 2012 (UNHCR, 2012).

In terms of land use, Uganda has a total area of 241,550.7 (GoU, UBOS, 2012) square kilometers. Approximately 41 percent (GoU, UBOS, 2012) of the land is cultivated (9 percent in permanent crops). The World Bank reported that 0.20 hectares per person was arable in 2009 and between 1980 and 2011 arable land increased from 53.5 to 70.4 percent (World Bank, 2011). Land pressure to cultivate has steadily increased over the last two decades, and given the consistent and strong population trend is expected to continue. According to a 2005 National Forest Authority Report, forests and woodlands cover a total of 4.9 million hectares, about 24 percent of the total land area; 30 percent in protected areas (1.9 million hectares of forest reserves, national parks, and wildlife reserves) (National Forest Authority, 2005). Cultivated land is encroaching on the protected areas and is projected to become a bigger problem as land pressure increases, gradually diminishing forest cover and the ecological services that forested ecosystems provide.

1.1.3 INSTITUTIONAL CONTEXT

To develop an understanding of constraints and opportunities inherent to climate change in Uganda and to identify realistic recommendations and options, a rapid assessment of the institutional context at the national and local government levels was conducted. This activity occurred during the scoping and assessment phases. The primary national institutional actors are:

- The Climate Change Unit (CCU) in the Ministry of Water and the Environment (MWE);

- The Uganda Department of Meteorology (DOM) in the MWE, which is also the focal point for the United Nations Framework Convention on Climate Change (UNFCCC);
- The Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF);
- The National Agricultural Advisory Services (NAADS), which is multi-donor funded and semi-autonomous;
- The National Agricultural Research Organization (NARO), headquartered in Entebbe, and 15 public agricultural research institutes; and
- Other institutions conducting agricultural research, such as Makerere University and the International Institute for Tropical Agriculture (IITA).

Despite the fact that the Ugandan government is only in the initial stages of climate adaptation preparedness, progress is well underway to bolster national institutions working to address climate change and to approve a National Climate Change Policy and a Costed Implementation Strategy for the policy. At the national level, the government appears to recognize the need to strengthen leadership, coordination, and capacity to develop and implement a coherent national response. The establishment of the Climate Change Unit in the Ministry of Water and the Environment provides an institutional mechanism with which to do this.

Nevertheless, climate change awareness is uneven throughout government, and different ministries and agencies—vertically and horizontally—plan, invest, and implement separately. At the national and local government levels, climate change is associated with disaster risk reduction and natural resource management with limited discrete planning and budgeting for climate change activities. Development funds are limited relative to operational funds because funding flows and mandates filter down through line ministries. While local government staff address climate change through natural resource management and disaster risk reduction activities, agricultural staff and activities rarely focus on climate change. Moreover, at the local level, there remains a dearth of staff dedicated to working on climate change.

Now is an opportune time to support the organizational development and capacity building of Ugandan institutions so they are better prepared to understand and address the projected impact of climate change. A number of opportunities to strengthen the development of institutional capacity are emerging at the national and local levels. At the national level, for example, it is important to support the development of a high-level, multi-sectoral body led by the CCU to strengthen the climate change mandate and guide policy development, coordination, and investment. Given Uganda's bio-physical and cultural diversity, a priority institutional development strategy would be to support the mandate and ability of research institutions to develop—through innovation and research—applied solutions to the impact of climate change specific to the Ugandan and subnational context. It will be essential to build the capacity of the CCU and other supporting agencies (NARO, DOM, and universities and national and private research organizations) to research the intersections between climate and agriculture.

Agricultural extension and service delivery institutions should be strengthened to institutionalize, apply, and replicate evidence-based management practices and technologies that have been developed through research efforts. Examples include the development of climate-adapted varieties, provisioning of inputs and information to farmers, and development of climate change monitoring and early warning systems. It will also be necessary to improve government capacity—at national and sub-national levels and across sectors—to deliver agricultural services, improve the management of natural resources, and promote alternative livelihoods for farming households. A description of specific institutional recommendations is included in Section 3 of this report.

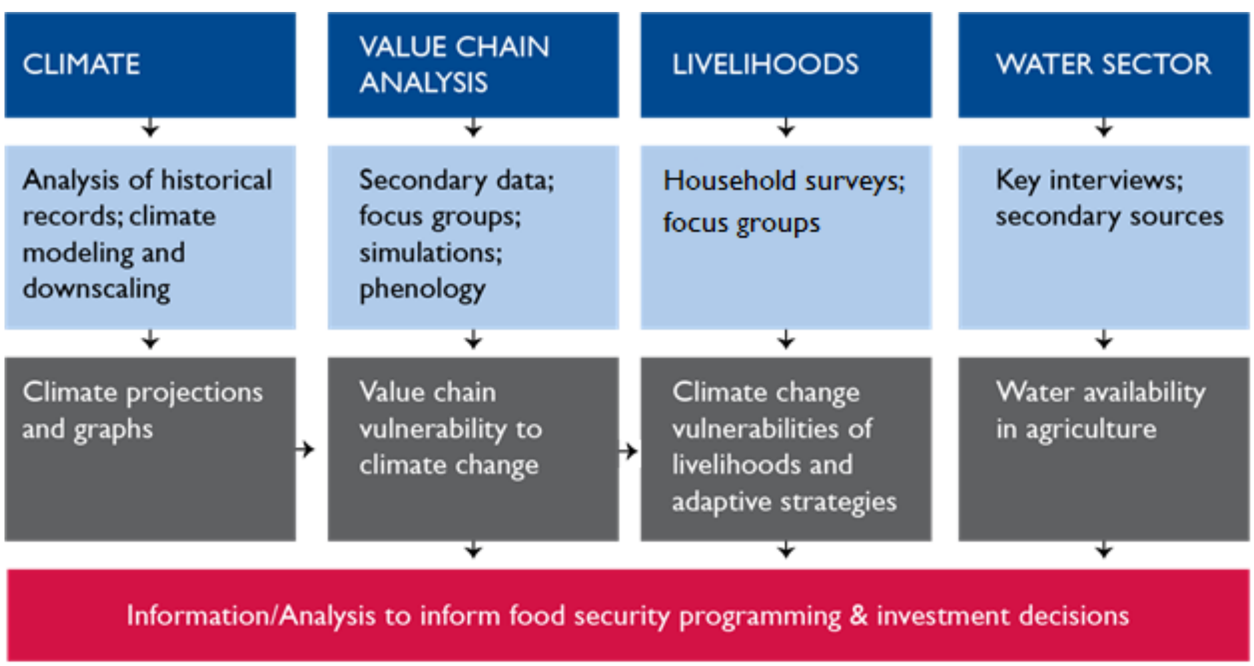
1.2 METHODOLOGY

1.2.1 OVERVIEW

The methodology for the integrated assessment follows the widely accepted definition that livelihood vulnerability is a function of exposure to a stressor, in this case climatic; the sensitivity of a livelihood or household to the stress associated with that exposure; and the adaptive capacity to recover from the impacts of that exposure. All households are exposed equally to a stressor within the same geographical area, but the levels of sensitivity and adaptive capacity vary. The sampling frame was constructed around six agricultural districts (Gulu and Lira—central north; Luweero and Mbale—center and central east; and Isingiro and Kasese—south and west). These were selected because they are USAID Feed the Future priority districts and represent national agro-ecological variability that includes priority cropping systems and proximity to climate stations that collect credible precipitation and temperature data. Figure 1 illustrates the methodology, which has several analytical components, including:

- A climate analysis;
- A value chain assessment of the selected crops: maize, beans, coffee, matooke, rice, cassava, sweet potato, and sorghum;
- Phenological review of the selected crops;
- A quantitative and qualitative livelihoods analysis;
- An institutional analysis; and
- An assessment of water use for agriculture.

FIGURE 1. UGANDA VULNERABILITY ASSESSMENT METHODOLOGY



The climate change analysis has two elements: A **historical analysis of 60 years**, comprising two periods (1951 to 1980 and 1981 to 2010) of climate data on precipitation and temperature, compared to establish climate change trends; and **projections of climate change and variability** using 10 different climate change models and two emissions scenarios to estimate temperature and precipitation changes into 2030.

The **value chain analysis**, using secondary sources, examines the sensitivity of the eight selected crops to the projected changes in climate along the value chain. A **phenological review** was also conducted for the selected crops, based on secondary data, to assess how the projected changes in rainfall and temperature may affect the requirements necessary for the growth cycle of each crop as well as associated diseases and pests.

The livelihoods analysis included quantitative and qualitative components:

- **A quantitative household survey** was conducted to assess how climate variability and change are experienced at the household level—directly through household production systems, and indirectly through its impact on the commodity value chain. Two sub-counties were selected at random from each district; three villages from each sub-county (six villages total); and 20 households from each village, for a total of 120 households (800 households all together).[1]
- **Qualitative focus group discussions** (FGDs) were conducted to determine more detailed perceptions of changes in climate stress and the corresponding behavioral responses. The outcome of the qualitative focus group sessions helps to explain the patterns that emerge from the quantitative work. In each village, two FGDs were conducted separately, one with men and one with women, generating a total of 80 FGDs.

A separate **water sector assessment** was conducted based on secondary data to assess the impact of climate change on available water resources for agriculture (irrigation), livestock, human consumption, and the protection of critical wetlands (abundant in Uganda). Finally, **key informant interviews** were conducted at the national and district levels with government and civil society policymakers, the academic community, and service providers. The goal was to understand the institutional context in which to develop climate change policy and programming.

[1] Using available census data, it was determined that five of these districts share a similar population size, but Kasese supported a significantly higher number of households. The sample size was thus determined to be 120 households for each of the five districts and 200 households for Kasese.

2.0 THE INTEGRATED ASSESSMENT FINDINGS

As stated above, vulnerability is defined here as a function of three factors: exposure, sensitivity, and adaptive capacity.[2] In this assessment, "exposure" represents a multiple set of changes in climate. Under local conditions, this set can manifest as alterations in the amount and distribution of rainfall, temperature, humidity, and the frequency and severity of extreme events, in addition to second-order impacts on disease and pest vectors as well as other biotic communities. As part of the vulnerability equation, sensitivity links these elements of exposure to human systems integrated with natural systems. This assessment shows, for example, how changes in climate can affect the viability of specific agricultural crops and the farmers that grow them, and thereby define them as displaying higher levels of sensitivity. Adaptive capacity is the inherent ability of a livelihood system, or a household, to absorb climate change shocks and to buffer their impacts. It is often described as recovery power, or as a set of assets and strategies that result in livelihood resilience. According to traditional understanding of vulnerability, the most vulnerable livelihoods/households are those with high exposure, high sensitivity, and low adaptive capacity.

This assessment systematically analyzes the vulnerability of farmers in the six targeted districts by tracing expected patterns of climate change and its impact on key crops grown by farm households. It also estimates the sensitivity and adaptive capacity of these households to adjust to changes in the natural system. The presentation of integrated findings begins with a description of exposure to climate change in Section 2.1. The report then describes sensitivity to climate change in Section 2.2. The impact of projected changes in climate was analyzed against an analysis of the eight selected crop value chains that constitute the core of Ugandan agriculture, supplemented by a phenological review of the eight crops. The crop sensitivity section is followed by the results of the livelihood analysis, which categorizes the overall vulnerability of the 800 sample households by evaluating their relative sensitivity to projected climate changes. Results of an analysis of the effect of climate change on water, a critical resource, are then presented. Section 2.3 of the integrated findings section—on adaptive capacity—is based on the analysis of how the selected crops, households, and communities may absorb and adapt to the anticipated climate change impacts.

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[2] This is often presented in the model V (vulnerability) = f (exposure, sensitivity, adaptive capacity). (B. Smit and J. Wandel, 2006).

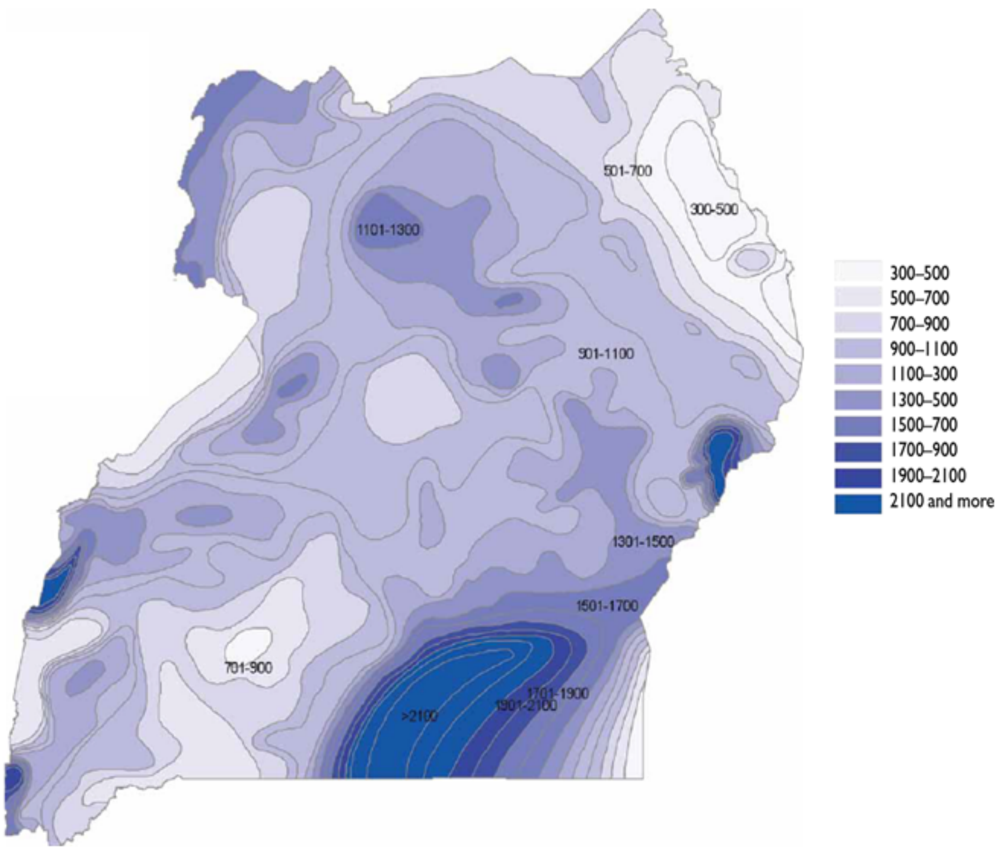
2.1 EXPOSURE TO CLIMATE CHANGE

2.1.1 GENERAL CHARACTERISTICS OF CLIMATE IN UGANDA

Average Climate

Although all of Uganda lies within a relatively humid, equatorial climate zone, geographic features such as topography, prevailing winds, lakes, and rivers cause local variations in annual precipitation and temperature,[3] leading to large differences and a relatively complex pattern of annual rainfall (Figure 2). Furthermore, rain falls during two seasons in the south of the country, progressively merging into one rainy season as one moves north and eastward. The seasonality of rainfall is linked to the seasonal migration of primary humid air masses and convergence zones over Africa that shift toward a northerly location in August and to the south in January.

FIGURE 2. AVERAGE ANNUAL PRECIPITATION IN UGANDA, IN MM/YEAR



Source: Ugandan Meteorological Service.

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[3] Locations a few miles apart may experience different local climate depending on whether the location is at the bottom of a valley or on the slopes of mountains, affected by moisture from a lake or the shadow of a mountain range. Those differences can induce large differences in conditions suitable for different crops, further modulated by soil characteristics and farming practices.

Climate Variability

To date, peer-reviewed climate studies of Uganda have focused primarily on the regional scale because of the greater availability of data for the east African region as a whole. Current climate variability within the region is mostly related to sea-surface temperatures (SST) in the tropical Pacific and Indian Oceans, and to a lesser extent the Atlantic Ocean (Mutai and Ward, 2000; Camberlin et al., 2001).[4] In particular, warm El Niño Southern Oscillation (ENSO) events tend to lead to more rain during the latter part of the September to November (SON) season, with lesser influence over the March to May (MAM) and June to August (JJA) seasons (Nicholson and Entekhabi, 1987; Mutai and Ward, 2000; Camberlin and Philippon, 2002).

The Indian Ocean also influences the regional climate (mostly during the SON rainy season), during what is referred to as Indian Ocean Dipole Events. The dipole events seem to have a stronger impact than ENSO (Black et al., 2003; Philippon et al., 2002), although SST variability in both oceanic basins seems not to be fully independent (Black et al., 2003). The east African region is not known for a strong decadal variability, although recently Lyon and DeWitt (2012) identified a decline in MAM rainfall at the regional scale, persisting since 1999 and linked to an unprecedented anomalous SST pattern in the Pacific Ocean. The SST pattern seems responsible for the observed dry conditions in the region, while long-term projections point to consistent increase in precipitation (Cf. IPCC, 2007). This dichotomy points to the importance of inter-annual and decadal variability versus long-term trends for planning in climate-sensitive sectors.

2.1.2 OBJECTIVES AND PRESENTATION OF THE CLIMATE ANALYSIS

The objectives of this climate analysis are to (1) analyze the recent variability of climate—including its longer-term evolution, with sufficient differentiation between agro-ecological zones in Uganda; (2) provide a context for the projected changes in climate; and (3) present and analyze downscaled climate projections in different agro-ecological zones within Uganda. The climate section of this report presents data and methods based on historical and projected climate analyses. It also includes the main findings from a historical climate analysis, focusing on long-term climate evolution in Uganda, the main conclusions concerning the projected changes in climate around 2030, and a summary of its most salient points.

2.1.3 DATA AND METHODS

Data

Given the complex topography and local influences on Uganda's climate, a high-density observational network would be required to correctly document the diversity of climatic conditions. Despite a relative lack of monitoring capability, the Uganda Meteorological Service currently operates approximately 50 rainfall recording stations, and another 12 that record minimum daily temperatures, with only six recording daily maximum temperatures (Figure 3, following page).

Many of the records are not digitized, nor are they stored in an easily accessible centralized repository. The study made a significant effort to recover some of the data (especially that associated with rainfall)

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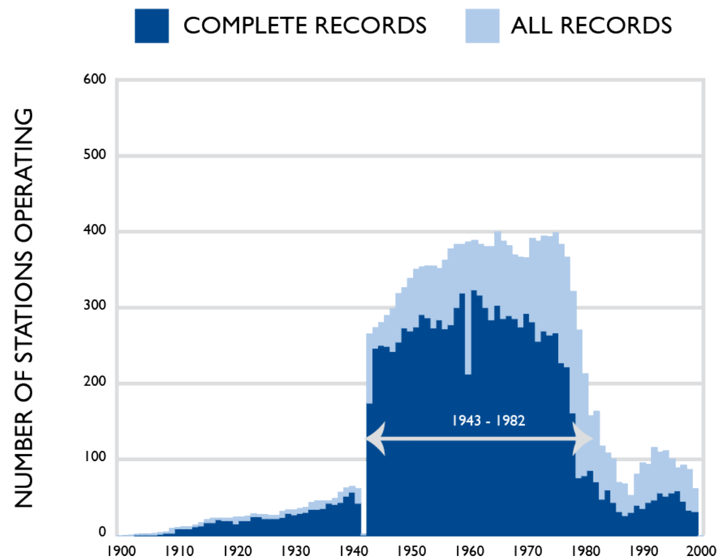
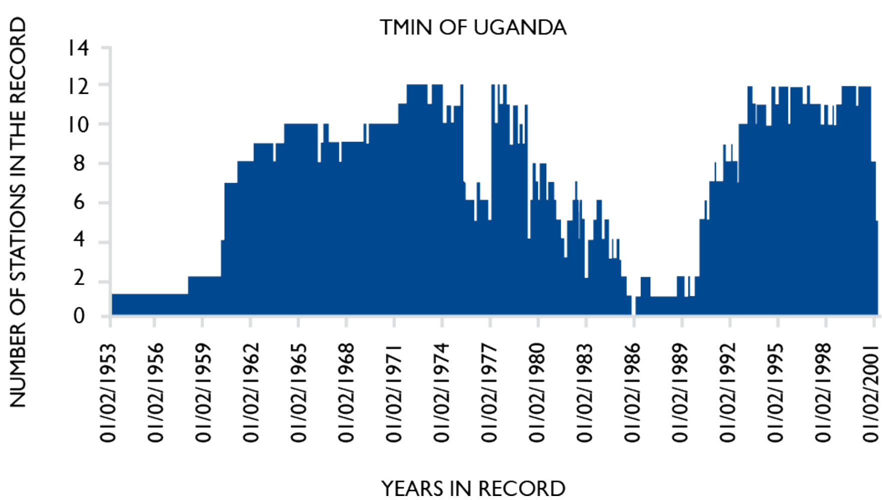
[4] SSTs affect wind circulation, moisture supply and timing of moisture convergence and rainy seasons. The Atlantic and Indian Oceans directly affect those features, while SSTs in the Pacific Ocean affect atmospheric circulation via a complex chain of reactions, involving upper layers of atmosphere during ENSO events.

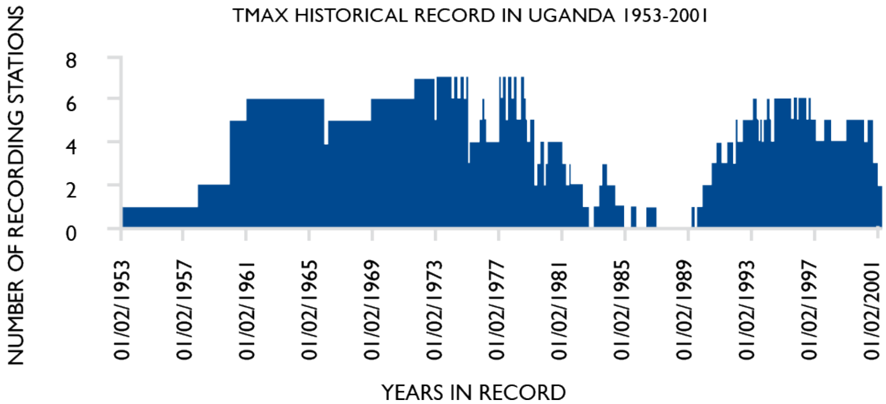
directly from *in situ* records and established a comprehensive and documented dataset. Daily rainfall records recovered from approximately 50 stations were digitized (Figure 4) with a special focus on 16 representative stations where the quality of the data has now been thoroughly assessed.

Rainfall records of the 16 selected stations have minimal missing data (averaging less than 4 percent, with most less than 2 percent) over the period 1950-2010, with the maximum percentage of missing data over 30-year periods never exceeding 7 percent. Thus, the temporal quality of the data covering the 60-year period is relatively accurate, even though the geographic coverage is more limited.

FIGURE 3. TIME SERIES OF THE NUMBER OF REPORTING STATIONS IN UGANDA (TOP—DAILY MINIMUM TEMPERATURE; MIDDLE—DAILY RAINFALL; BOTTOM—DAILY MAXIMUM TEMPERATURE)

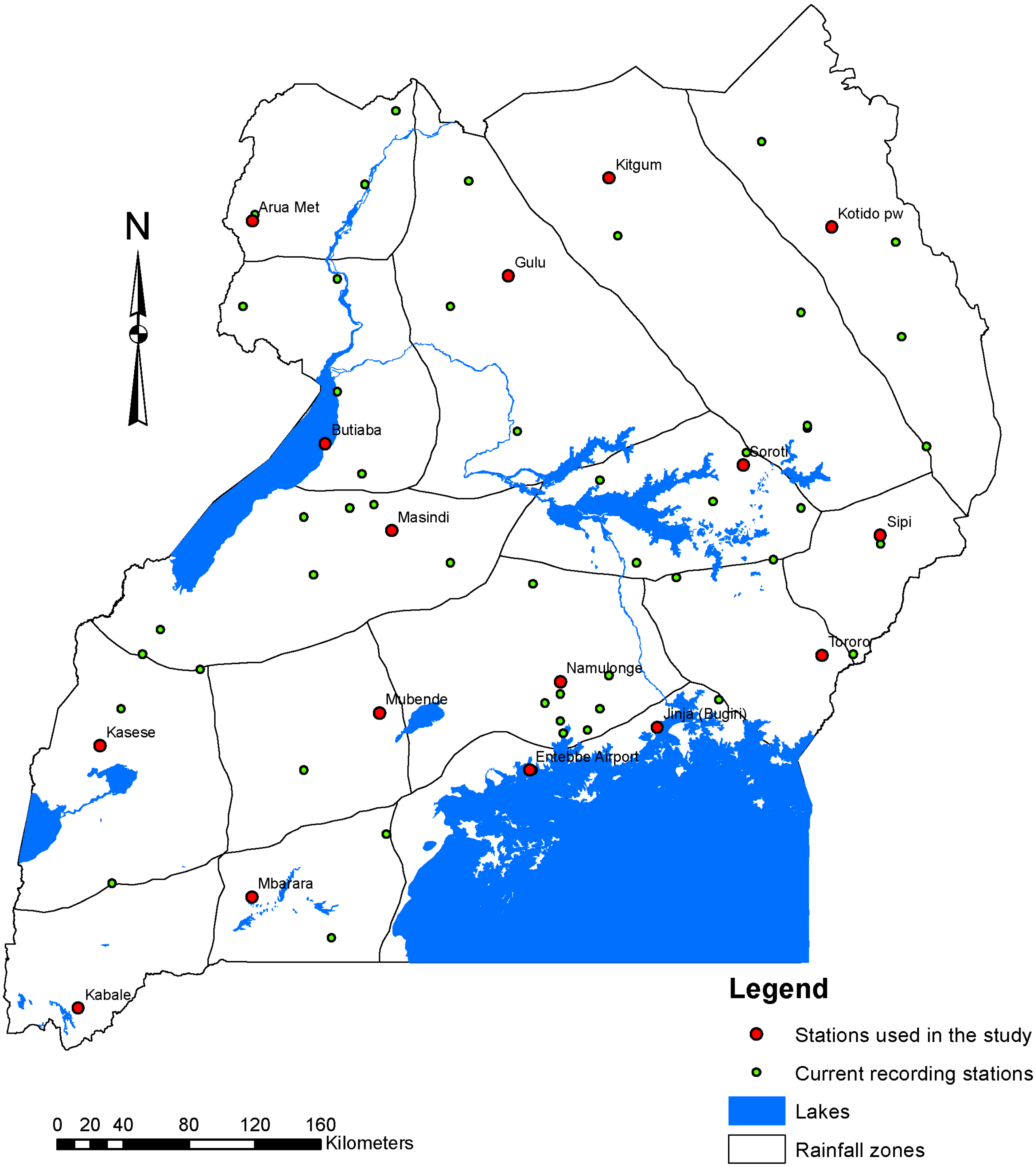






Source: Uganda Meteorological Service.

FIGURE 4. WEATHER RECORDING STATIONS USED IN THE CLIMATE CHANGE VULNERABILITY ASSESSMENT FOR UGANDA



Note: Smaller dots represent 16 climatic zones currently defined by the Ugandan Meteorological Service and stations currently recording daily rainfall. Larger red dots represent stations used in the study—1 per zone.

Climate Regionalization

While the topography and local influences from numerous large water bodies lead to complex climatic patterns in Uganda, it is useful to partition the country into a manageable number of regions or zones that share similar characteristics, such as ecological or agro-ecological zones. In this study, the country was divided into distinct zones as defined by Basalirwa (1995), based on an objective analysis of seasonal cycles of monthly rainfall in more than 100 rainfall stations that collected data between 1940 and 1975. This analysis was further amended by the Meteorological Service[5] to 16 climatic zones (Figure 4). Sixteen stations were selected as representative, to some degree, of each zone and their records carefully updated, qualified, and analyzed. Among those stations, six of the stations also log temperature data. The selection process ensured relatively close proximity of the stations to the six districts encompassed by the Uganda VA.

Methods

Analysis of historical records

Although perceived as an intrinsic characteristic of a given location or region, climate is not a steady state and varies on a number of spatial and temporal scales. Natural vegetation and humans have both adapted to these variations. Therefore, the challenge of climate change projections lies in determining to what extent the future climate will depart from the current state, whether in its mean state or in its variability.

To give a sense of the scale of this evolution, it is important to contextualize it with respect to the current climate and its variability—inter-annual to decadal—as well as to observed trends. To do this, rainfall records from the 16 representative stations and maximum and minimum temperature records for the six stations have been analyzed.

Average climate and inter-annual variability

Researchers typically characterize climate over periods of 30 years with long-term averages of rainfall and temperature (annual, seasonal, monthly values) as well as the description of their variability. Other important climatic features include onset, cessation, and length of rainy seasons and their variability, in addition to statistics highlighting daily events. The current climate is characterized by computing the following:

- Thirty-year averages of annual, seasonal (for sets of months DJF, MAM, JJA, and SON) and monthly rainfall amounts as well as average maximum and minimum temperature;
- Thirty-year averages of onset, cessation, and length of the rainy season; and
- Standard deviation of the above to document inter-annual variability over the same period.

Long-term evolution of observed climate

Long-term evolution of observed climate is often assessed by adjusting linear trends to time series of annual or seasonal values. This can be influenced by decadal variability or period length and does not

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[5] This study will be difficult to update because most of the recording and reporting stations used in the study are no longer in operation (Cf. Data section above).

relate trend amplitude to inter-annual and decadal variability. In this study, the long-term evolution of climate in Uganda is characterized by directly comparing the main climate characteristics computed over two 30-year periods: 1951-1980 and 1981-2010. This approach allows the use of standard statistical techniques to evaluate whether two samples belong to the same or different populations. It also enables researchers to assess whether the climate observed during those discrete periods has altered beyond the fluctuations normally observed during sampling.[6]

Projections of Climate in Uganda

Sources of projected climate

General Circulation Models (GCMs) allow scientists to collect information about the projected evolution of climate, based on numerical representations. These models rely on information concerning greenhouse gas (GHG) emissions, which alter the composition of the atmosphere and in turn affect energy budgets, atmospheric and oceanic behaviors, and ultimately local climate.

To ensure the best available estimates of future climate are included in this study, new projections have been used. These projections were prepared for the next Intergovernmental Panel on Climate Change (IPCC) assessment and have been made available since December 2011 (Taylor et al., 2011). Despite constant progress in the scientific knowledge of climate and its processes, improvement of computational resources, and innovative technical solutions, researchers estimating changes in the future climates—especially at the local scale—face a number of challenges:

- **Scale issues, downscaling approaches, and systematic bias correction—Delta Method.** The need to solve thousands of equations in hundreds of thousands of locations over a period of 100+ years and the current computational capacity constrain the spatial resolution of the models and the number of processes that can be explicitly modeled. Thus, models are only approximate representations of the system, using current knowledge and technologies. For example, models might not capture differences in temperature and rainfall between two locations: one lying at the bottom of the valley and the other, higher in the mountains. To capture these differences, downscaling procedures and bias correction need to be applied.

  A simple adjustment of average annual, seasonal, and monthly temperature minimums (T-min) and maximums (T-max), as well as rainfall used in numerous climate projections (Ramirez-Villegas and Jarvis, 2010) was applied during this study. The method consists of computing changes in temperature and rainfall projected by a given model, relative to the values produced by the model for the current climate, and applying the changes to rainfall and temperature values observed in the 16 stations.[7] The statistical significance of the change in averages, as well as variance, is assessed relative to the model's own variability using standard statistical tests. Only monthly to annual values are used in this study because daily values, notably for rainfall, are unreliable in the models.[8]

6 We have used standard student's T-test to evaluate the significance of changes in long-term averages and the Fisher-Snedecor F-test to evaluate changes in variability.

7 For example, a 10 percent increase in annual rainfall means a 160 mm increase in a location where the observed rainfall is 1,600 mm/year, and only 90 mm if the station records 900 mm/year on average.

8 Climate models cannot explicitly resolve the processes controlling rainfall. Instead, they use empirical relationships between rainfall and other atmospheric variables, a technique called parameterization. Parameterizations are calibrated in a way to ensure that "climatic"

Complex bias-correction procedures would need to be applied to infer changes in intra-seasonal characteristics that have a very high degree of uncertainty. Only projections for the 30-year period centered on 2030 are discussed.

- **Assess uncertainty—using a multi-model approach and two scenarios.** The technical challenges inherent in climate modeling as described above have led different modeling groups to vary their technical approaches, which may result in slightly different projections. At this stage, it is impossible to select the 'best' models, as multiple and broad criteria are used to evaluate climate change and its impact.[9] Thus, the current approach recommended by the IPCC—also known as the multi-model approach—is to incorporate projections provided by all groups and assess the spread among the results as a measure of uncertainty. This study focused on two emission scenarios, or Representative Concentration Pathways[10] (RCP 4.5 and RCP 8.5), and applied 10 different models developed by different groups, with different resolutions and only one version[11] per model.

2.1.4 CURRENT AND PROJECTED CLIMATE IN UGANDA

Average Climate in the 16 Zones

Average climatic conditions in Uganda (Figure 5) are characterized by two well-defined rainy seasons in the south of the country (e.g., Kabale, Mbarara), progressively merging into one season as one reaches northern locations (e.g., Gulu, Kitgum). It is important to note, however, that in the western part of the country, conditions are generally drier and the bimodal cycle more pronounced (e.g., Kasese vs. Entebbe or Jinja, Butiaba vs. Gulu).[12] Conversely, temperatures do not exhibit marked seasonal cycles or spatial variability. Thus, the seasonality of rainfall is the main—but not the only—driver of farming activities. Thriving agriculture in the southern regions testifies to the critical role of rainfall distribution throughout the year, as well as that of the soil quality and farming practices.[13]

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features, such as monthly, seasonal, and annual rainfall are captured as well as possible around the globe but not necessarily local daily rainfall that depend on local "sub-grid" scale conditions and mechanisms.

9 Model performance can be evaluated in terms of average climate, its variability, and long-term trends. Not all models perform equally well with respect to all categories.

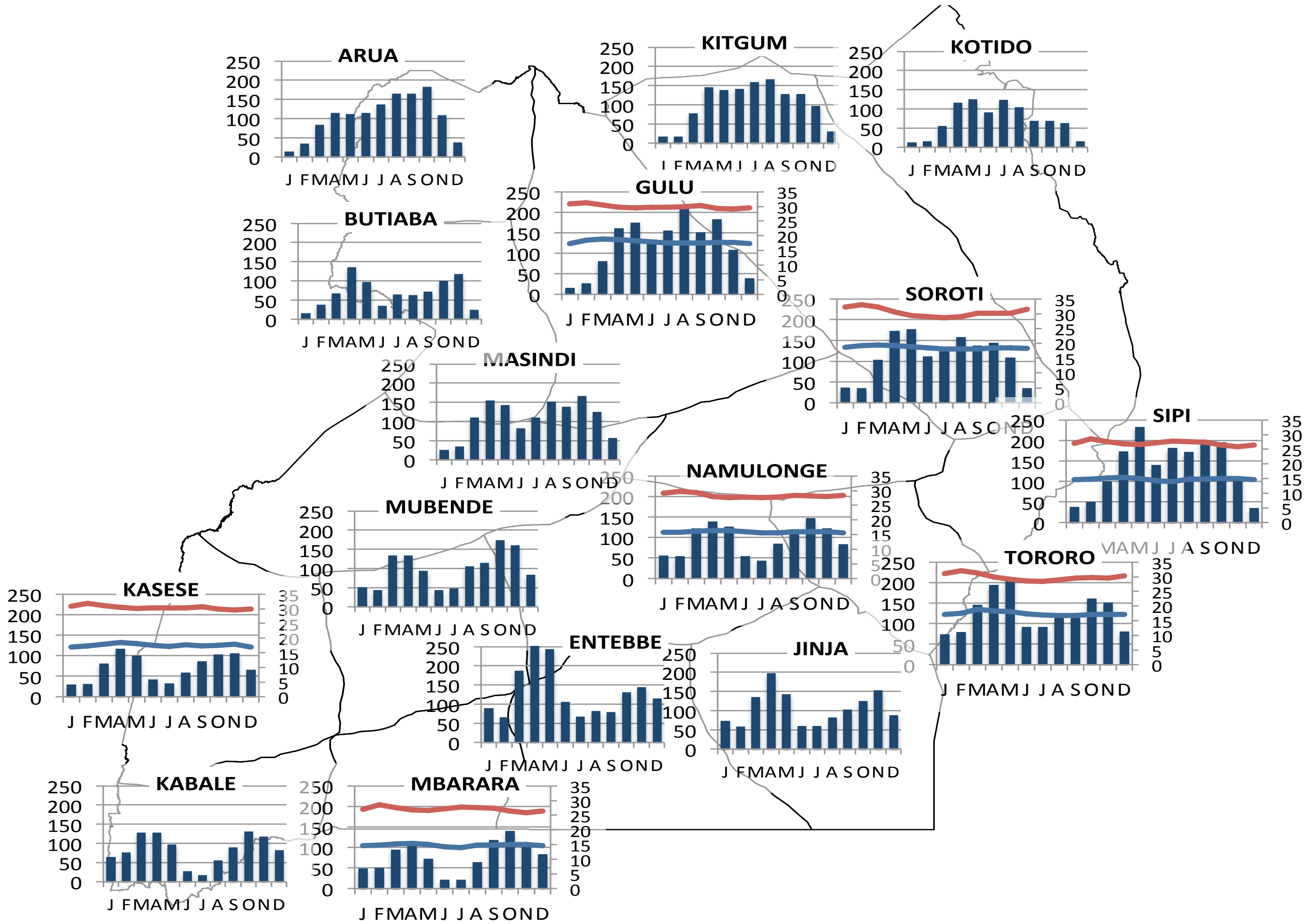
10 RCPs are not new, fully integrated socioeconomic narratives or scenarios, but rather pathways of radiative forcing. Information about RCPs and the scenario development process for the IPCC AR5 can be found in Moss et al. (2010). RCP 4.5 corresponds to a radiative forcing that stabilizes at 4.5 W/m^2 after year 2100, and corresponds to a lower possible emission path, while RCP 8.5 corresponds to a high path with a steady rise in emissions and a radiative forcing that exceeds 8.5 W/m^2 by 2100.

11 Several modeling groups have provided different versions of the same model; those versions can differ in their resolution or treatment/ representation of a particular process while keeping the bulk of the model the same (including several versions of the same model would bias the results, as versions of the same model usually produce results that vary less than outputs from different models).

12 Note also that regions in the south receive much less rainfall than central and northern regions (with the exception of Butiaba and Kotido).

13 Note that in southern stations, the driest season is JJA, with rainfall still reaching 100 mm/season. In the northern stations, DJF is the driest, season with seasonal totals well below 100 mm/season.

FIGURE 5. AVERAGE MONTHLY PRECIPITATION (BARS) AND MINIMUM (BLUE) AND MAXIMUM (RED) TEMPERATURE IN THE 16 CLIMATIC ZONES.

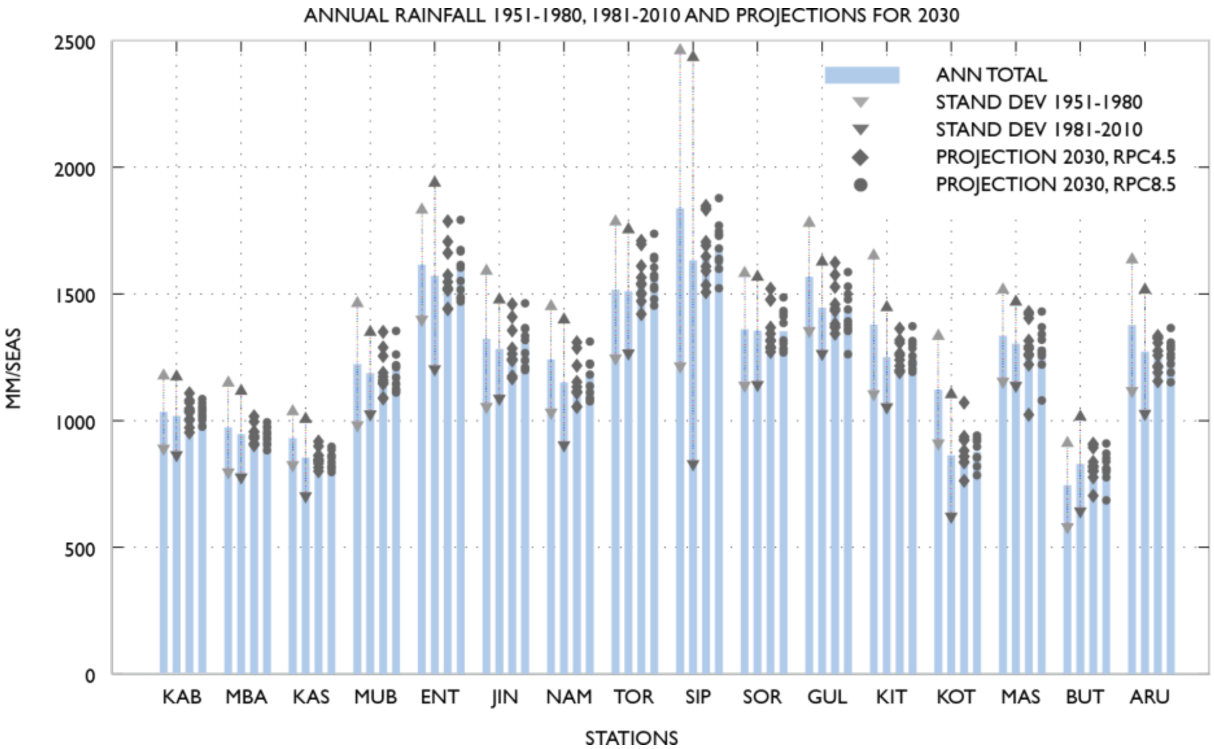


Note: Average computed over the 1981-2010 period. For comparison, rainfall and temperature scales are identical for all stations.

Climate Variability and Projections

Figures 6, 7, and 8 summarize the main characteristics of inter-annual and longer-term rainfall, and temperature variability in individual stations. Projected changes in rainfall and temperature with respect to observed long-term climate evolution average annual values computed over 30-year periods are compared in the figures. The arrows represent long-term changes with respect to observed inter-annual variability. Figure 7 represents onset and cessation of the rainy seasons, their long-term evolution, and inter-annual variations. To evaluate uncertainty in projected climate, in addition to 30-year averages of rainfall and temperatures derived from the multi-model ensemble, projections by individual models are shown in Figures 6 and 8.

FIGURE 6. AVERAGE ANNUAL PRECIPITATION IN 16 STATIONS (IN MM/YEAR; STATIONS LABELED WITH THE FIRST THREE LETTERS)



Note: Bars for annual totals: the first bar for each station shows average rainfall totals recorded for 1951-1980; the second bar for the 1981-2010 period. Both show respective standard deviations as arrows. The third and fourth bars show annual rainfall amount projected for 2030 in RCP 4.5 and RCP 8.5 scenarios, respectively. The bars indicate the multi-model average, while the diamonds and squares show the annual total projected by individual models to illustrate the range of predicted values. Projected average amounts were computed as 30-year averages over the period centered on 2030 (i.e., 2015-2045). Note that the ranges for observed values refer to variations computed over time, while ranges for projected amounts refer to the projections by different models; they are not equivalent. Evaluation of the projected change in the amplitude of inter-annual variability has also been done but is not represented in this figure.

Observed rainfall and its variability

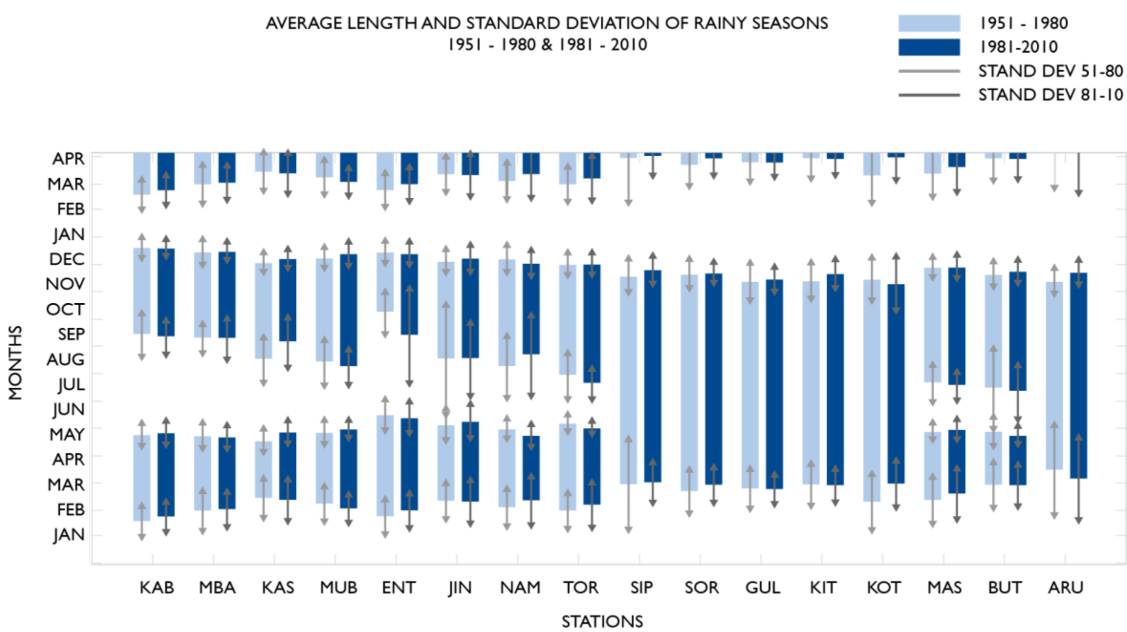
- **Annual totals.** The 30-year average annual precipitation in each station is shown as bars on Figure 6. Several stations (Entebbe, Tororo, Sipi, and Gulu) record around 1,500 mm of rainfall per year, while some (Kabale, Kasese, Mbarara, Kotido, and Butiaba) record less than 1,000 mm per year. The differences between the 1951-1980 and 1981-2010 periods, illustrated by the two first bars for each station, point to a very small decrease in precipitation between those two periods. This decrease is modest with respect to overall levels of annual precipitation in each station, as well as with respect to the amplitude of inter-annual variability in each period (illustrated by the arrows at the tip of each bar). It is easy to see that the differences between the two first bars in each station are much smaller than the amplitude indicated by the arrows. The latter is important and ranges between 13 and as much as 30 percent of annual totals, depending on the station.

  The significance of the long-term change is assessed with respect to the inter-annual variations; the only stations where decreases are significant are northern Gulu, Kitgum, Kotido, and Kasese. Further investigation of the seasonality of the decrease observed points to the SON season for the northern stations and JJA season for Kasese. In both cases, the decrease occurred during the main dry season and points to potential links to larger-scale climate variations. Long-term changes in variability, inferred from comparison of the amplitude of inter-annual variability, were mostly not significant and revealed no spatial or seasonal consistency among the stations.

Overall, the results do not point to strong long-term changes in precipitations in Uganda. However, the results do not exclude shorter-term changes in rainfall and its variability, linked to natural variability of climate and not captured in this analysis.

- **Intra-seasonal characteristics.** Similar to annual and seasonal total rainfall, the onset, cessation, and the length of each rainy season, captured in Figure 7, reveal significant inter-annual variability during both 30-year periods (arrows). Also, changes in the onset, cessation, and length of the season between these periods are small compared to the inter-annual variability and are rarely significant statistically. No overall trend, or spatial pattern, has been detected.[14] This finding means that the variations cannot be attributable to long-term climate change. Nevertheless, this again does not exclude the possibility that shorter-term changes (e.g., those related to climate variability) might have occurred as farmers have noted. Further exploration of inter-annual rainfall variability and its causes is therefore required to arrive at more accurate information concerning climate change-related rainfall patterns in Uganda.

FIGURE 7. COMPARISON BETWEEN AVERAGE RAINY SEASON CHARACTERISTICS COMPUTED OVER 1951-1980 (LEFT BARS) AND 1981-2010 (RIGHT BARS) IN 16 STATIONS IN UGANDA



Note: Onset and cessation dates are placed on the vertical axis with stations on the horizontal axis. Rainy seasons are depicted as bold blue bars with +/-1 standard deviation of the onset and cessation indicated as arrows. The onset of the first rainy season is repeated at the top of the figure to capture the DJF dry season.

[14] Both delays and advances in onset and cessation have been observed—in addition to changes in the length of the rainy season—but with no specific spatial pattern.

- **Rainfall projections.** Projections for the 2030 horizon (Figure 6) on average point to a small, but not significant, increase in annual rainfall totals. For both scenarios, those changes are much smaller than the inter-annual variability. Moreover, individual models disagree on projected changes in rainfall and conclude that increases as well as decreases—some of them significant—will take place but with no preferred tendency among the models. Inspection of seasonal and monthly rainfall amounts points to a similar conclusion, with the notable exception of the DJF dry season. This dry season shows a significant overall increase in precipitation as predicted by the multi-model ensemble, due mostly to one model projecting a very strong increase in rainfall for this season. Further investigation is required to determine the extent to which precipitation could increase.

Observed temperature and its variability

- Unlike for rainfall, the inter-annual variability of average annual minimum and maximum temperature is very small (Figure 8).[15] Nevertheless, comparisons of long-term averages between 1951-1980 and 1981-2010 show a statistically significant overall increase in average annual temperatures[16] on the order of 0.5-1.2 °C for minimum temperature (T-min) and 0.6-0.9 °C for maximum temperature (T-max). No significant differences in the amplitude of this increase between seasons were found.
- **Temperature projections.** Models agree on the continuation of the already observed increasing trend in temperatures by 2030, with average projected increases on the order of – 0.8-0.9 °C in T-min and 1.2-1.4 °C in T-max under the lower emission scenario, and slightly higher in the higher emission scenario. Several models project an increase exceeding 2 °C. These values point to a trend toward higher average temperatures than those observed to date. No season stands out as warming significantly faster than others.

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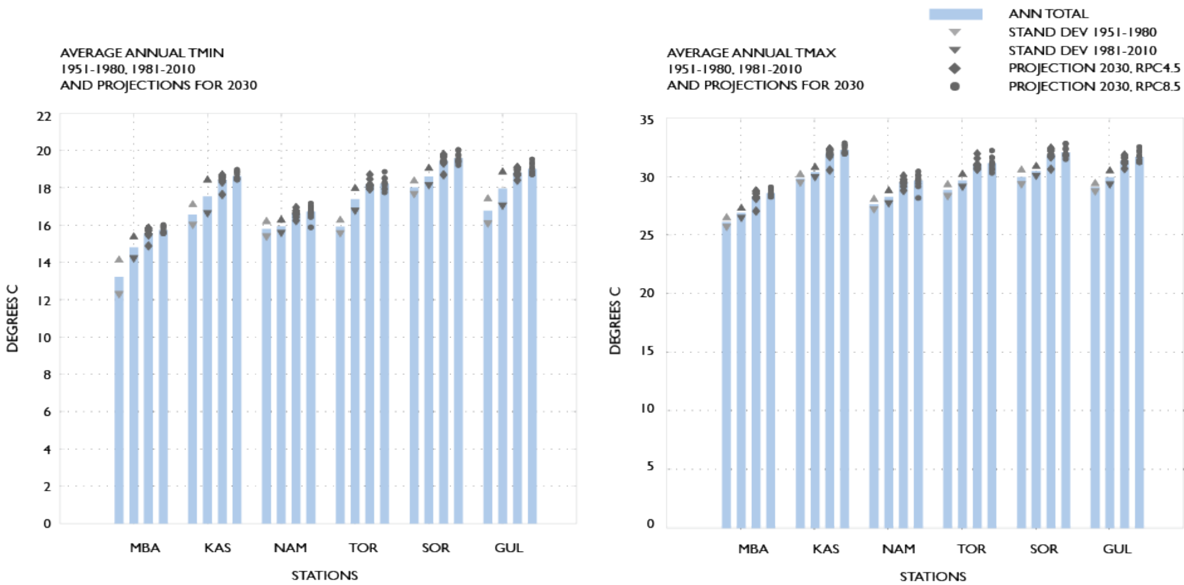
[15] The analysis is based on records available in only six locations. These locations, however, span different rainfall regimes, thus conclusions drawn here are expected to be valid in different climatic zones.

[16] No analysis of the frequency of extremely hot or cold days has been carried out in this study.

FIGURE 8. MINIMUM (LEFT) AND MAXIMUM (RIGHT) ANNUAL AVERAGE TEMPERATURE OBSERVED AND PROJECTED IN SIX INDIVIDUAL STATIONS



Note: See caption in Figure 6 for details.

2.1.5 SUMMARY AND CONCLUSIONS

This analysis has been constrained by the relatively sparse long-term record of observed rainfall, temperature values in particular, and a lack of documented peer-reviewed literature concerning past and current climate variability in Uganda to support and/or corroborate the findings. The threat of climate change to Ugandan livelihoods warrants a more thorough analysis of past variability and its impact on climate-sensitive sectors, based on a consolidated database as well as the further development of robust projections at the country level.

The evaluation of livelihood exposure to current and projected changes in climate undertaken in 16 climatic rainfall zones (six for temperature) determined the following:

1. Current rainfall and temperature levels are suitable for agriculture throughout the entire country, although **local rainfall seasonality and elevation (lower temperatures) may impose limitations on crop portfolios and their vulnerability**.

2. Inter-annual rainfall variability is high; and long-term change, assessed for the 60-year period, falls well below the inter-annual variations. Thus, **no clear, climate change-related trend in rainfall could be detected**. Moreover, more detailed investigations of inter-annual variability and its causes should be conducted to better assess the amplitude and causes behind changes farmers have observed.

3. **No robust and significant change in average annual rainfall is projected for the 2015-2045 period** with respect to current conditions. Models project limited changes and disagree as to their direction. The most consistent finding is a **projected potential increase in precipitation during the DJF season (dry season in all locations)**. This increase could have a significant

impact on agriculture—especially perennial crops and post-harvest activities—and should be investigated further.

4. **A robust and significant warming signal** has been found across all temperature records. This warming is projected **to continue** at a slightly higher rate into the 2015-2045 period.
5. There is a **potential for increase in the frequency of extreme events** as hydrological cycles intensify in a warming atmosphere.[17]

The main exposure to climate change is likely to come from changes in temperature, which in some cases could reach a 1.5° C annual average increase by 2030 (and even more for individual months). This average is higher than the temperature increase observed during the past six decades. Rainfall levels are projected to change very little, and are likely to be within current levels of variability and observed long-term changes. Some models point to a potential increase of precipitation during the DJF season, which is the dry season in all locations in Uganda. The analysis of the impact of climate change on agriculture in Uganda should therefore focus primarily on how higher temperatures within current rainfall levels will affect the agricultural sector in the future, and secondarily on the impacts of changes in the seasonality of rainfall. Because of this possibility—and the likelihood—of more frequent intense rainfall events and heat waves, more robust methodologies should be used to investigate this issue further. Further investigation of current rainfall variability is also needed to better understand changes in rainfall patterns, notably variations in the timing of the rainy season, reported by farmers but not captured in the analysis of long-term changes. In particular, changes since 1999 that have already been documented at a regional scale should be further analyzed within the Ugandan context.

2.2 SENSITIVITY TO CLIMATE CHANGE

2.2.1 SENSITIVITY OF CROP VALUE CHAINS TO CLIMATE CHANGE

The sensitivity of the selected crops to climate change was analyzed. The crop analysis was based on assumptions (validated by the climate analysis) that temperatures would gradually increase over the next 30 years, and the current DJF dry season would eventually experience increased light precipitation. Assessing the suitability and phenology of selected crops in Uganda was difficult given the broad and diverse range of growing conditions—plant material and climatic factors—coupled with the lack of reliable secondary data. A crop suitability analysis was conducted to assess the potential suitability of the eight crops, but was not conclusive due to the model's shortcomings in taking into consideration the diversity of local variables. For this reason, this study's assessment of crop sensitivity to climate change relies heavily on the crop value chain analysis and phenological review.

Phenological Review

Known climate-related variables that alter crop phenology[18] and productivity include CO_2, radiation, temperature, crop characteristics, water, weeds, pests, diseases, pollutants, and the availability (or lack

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[17] Based on literature (IPCC, 2007), the "thermodynamic argument", stipulating that a stronger hydrological cycle may occur in a warmer atmosphere, points to the possibility of more frequent extreme rainfall events, which could lead to flooding, landslides, and so on.

[18] **Phenology** is the study of recurring biological phenomena and their relationship to weather, such as seasonal and inter-annual variations in climate. It is generally related to the effect of climate on the timing of biological events, such as first emergence of buds and leaves, or date of harvest (Hermes, 2004).

thereof) of nutrients. Often affected by climate change, these variables play an important role in crop life cycles and overall productivity. This section of the study drew upon existing literature, data, and research to (1) develop a better understanding of the major phenological characteristics (phenophases) of selected crops, (2) develop insights into how these crops are likely to respond to climate change, and (3) assess the potential impact of projected climate change on the overall productivity of the selected crops and implications for food security.

Agriculture is inherently a risky endeavor with a wide range of biotic and abiotic[19] (including climate) factors interacting in a dynamic fashion at various stages in the growth cycle to determine the productivity of a given crop or season. Not only do alterations in climate or weather influence the productivity of crops, they also indirectly affect biotic factors such as diseases, pests, vectors, and weeds, thereby creating conditions that either favor or impede growth and thus impact the crop in question.

All living things enjoy a range of conditions most optimal for growth and development at each phase of the life cycle. Nevertheless, they can continue to grow and produce under a much wider range of less optimal conditions—albeit not as optimally. In addition, the impact of changing temperatures or precipitation might interact in unexpected and contradictory ways. For example, certain conditions might favor the productivity of a given crop, but also favor the growth and proliferation of a particular disease or pest, which, if not controlled, will lead to lower yields or damaged crops. The tables in Annex C summarize the impact of changes in temperature and precipitation on crop development at various stages of the growth cycle, as well as on a selection of particularly troublesome pests and diseases that tend to pose the greatest risks to each of the crops under review.

To summarize, as shown in Figure 9, the extent of climate impact on the eight selected crops varied, with cassava and sweet potatoes showing the least vulnerability and Arabica coffee showing the most. The production cycle of Arabica, and to a less extent Robusta, are vulnerable to temperature increase and erratic rain patterns, while cassava and sweet potatoes are much less sensitive to temperature increase and changing rain patterns. In the middle of the vulnerability continuum fall sorghum, beans, matooke, maize, and rice, which are moderately vulnerable: although highly adaptable in later phases of development, sorghum is susceptible in the earlier phases; beans are susceptible to changes in precipitation and temperature during flowering and fruiting, as is matooke; maize is adversely affected by heat/drought during leaf development, stem elongation, and antithesis; and rice is susceptible during panicle development and flowering. The phenological phases of all crops are threatened to varying degrees by disease and pests that thrive in moisture and high temperatures (for a detailed description of how the phenological stages of each crop and related pests and diseases are affected, see Annex C).

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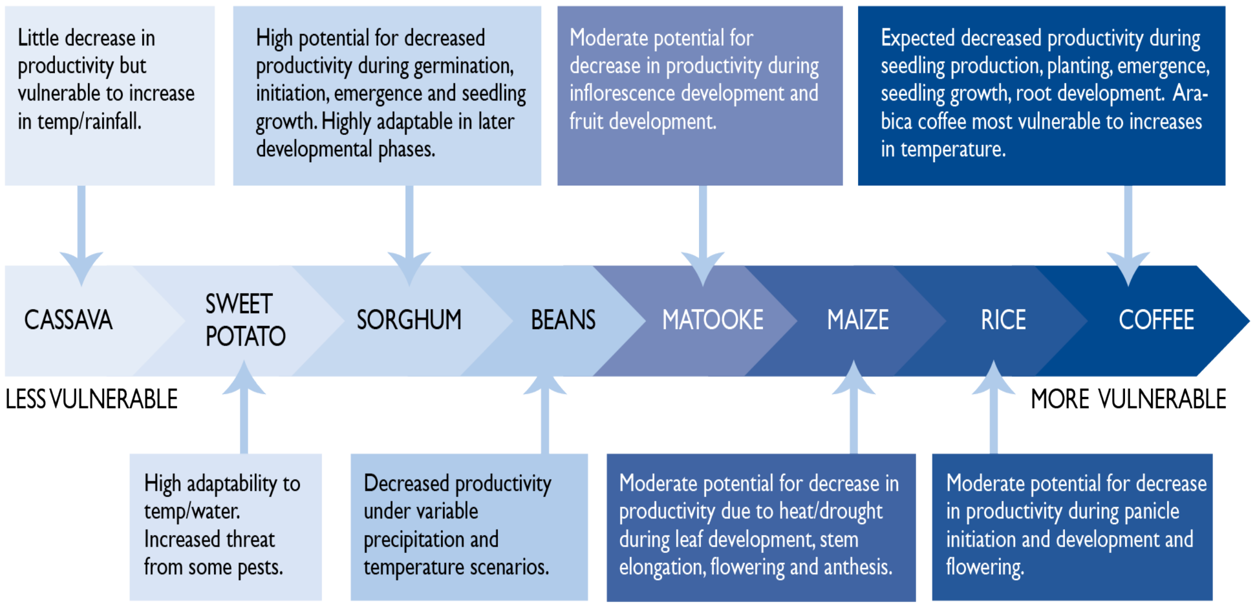
19 Abiotic factors are non-living chemical and physical factors in the environment, which affect ecosystems. In addition to climatic factors, this includes soil chemistry, nutrient composition, structure, and slope.

FIGURE 9. PHENOLOGICAL CLIMATE CHANGE VULNERABILITY CONTINUUM OF SELECTED CROPS



Value Chain Analysis

Climate change not only affects the crop life cycle, it also directly and/or indirectly influences the entire value chain, from pre-production to post-harvest storage, marketing to transport. For this reason, additional analysis of the value chain provides a more comprehensive assessment of the effects of climate on individual crop commodities. An analysis of the value chain examines the interrelationships and linkages between all actors that participate in the stages of the value chain—from input supply through production, processing, marketing, and end point consumption. Bottlenecks can cause inefficiencies that restrict supply, reduce profitability for producers and processors, and result in increased costs for consumers.

This value chain analysis takes the findings of the phenology study a step further, by looking at how climate impacts affect various stages of the value chain for different crops. Annex D presents a detailed value chain analysis for each of the eight selected crops, as well as summaries of their vulnerabilities, existing adaptation strategies, gaps, and options.

Value chain approaches by definition focus on a single commodity, but in assessing the overall risk and impact of climate change, it is important to consider the entire livelihood and food security status of households at risk. Integrating value chains is critical to assessing the big picture of how climate change affects a particular production system to capture the potential for adaptability and environmental sustainability and ensure economic rewards for all actors. It is also essential to note that many value chain actors provide services that cut across value chains at a particular node. As well, different aspects of the value chain hold potential solutions to climate change risk—whether it be supplying research services, input production and distribution, extension services, diversification of agricultural production, post-harvest handling, and/or marketing expertise.

Table I presents key comparisons between the selected commodities. The table compares the eight crop value chains relative to level of importance for livelihoods, food security, and the country strategy; integration of the value chains; and vulnerability to disease and climate. In terms of importance, matooke ranks high for both livelihoods and food security while moderately strategic in terms of national importance. Coffee ranks high in terms of national importance and livelihoods but low for food security. Maize is the number one strategic priority and is medium and high in food security and livelihoods, respectively. Beans also hold a high strategic ranking and ranks high for food security but low for livelihoods. Cassava has a similar ranking. While sweet potato, rice, and sorghum are less strategic from a national perspective, they rank high for food security. In terms of vulnerability to disease and climate, coffee is highly vulnerable to both; matooke and rice rank medium to high; beans and cassava rank medium; and maize, sweet potato, and sorghum rank medium to low.

TABLE I. OVERALL COMMODITY COMPARISON

	Maize	Coffee	Beans	Cassava	Matooke	Sweet Potato	Rice	Sorghum
Level of Strategic Priority (DSIP)	1	2	3	4	5	6	7	8
Time of Introduction 1= indigenous, 2=pre-colonial & colonial, 3=recent	2	1 R 2 A	1	2	1	2	3	1 F 3 S
Importance for Food Security	Med	Low	High	High	High	High	Med	High
Importance for Livelihoods	High	High	Low	Med	High	Low	High	Med
Level of Integration & Commercialization of Value Chain	High	High	Low	Med	Med	Low	High	Low F High S
Vulnerability to Disease	Low	High	Med	High	High	Med	Med	Low
Vulnerability to Climate	Med	High A Med R	Med	Low	Med	Low	High	Med

Key: A=Arabica and R=Robusta, F= Sorghum for Food, and S= Sweet Sorghum for Brewing

The following section briefly summarizes the results that emerged from the value chain analysis.

- **Coffee and matooke.** Coffee and matooke are both perennial crops native to Uganda and evolved in the humid tropics. Uganda has the highest per capita consumption of matooke in the world. Coffee is often grown with matooke as an intercrop, despite earlier attempts to promote mono-cropping. Land area planted with matooke trees and the number of matooke producers is roughly double that of coffee. Production of both crops is highly commercial but still dominated by smallholders rather than large estates. The average producing household owns approximately 1.2 ha of coffee, while the average for matooke is only 0.3 ha. Production was initially concentrated in central Uganda but has increasingly moved westward in the face of urbanization, labor shortages, declining soil fertility, and the rising cost of land in the central region. The production of both commodities fell drastically after 2000, following a disease epidemic (coffee and banana wilt diseases), which seriously damaged many trees from both crops. Replacing aging and diseased trees represents a considerable challenge because of difficulties in producing and distributing disease-free plants or improved/resistant varieties. Seedlings are highly perishable and nursery quality control is poor.

The value chain for each is complex, with large numbers of players involved, but coffee is complicated because it is an internationally traded commodity and is heavily dominated, at the marketing and processing end of the chain, by large multinational trading firms. Matooke, on the other hand, is both a subsistence crop and traded on the national market with a fairly large proportion of production channeled into the urban markets. Matooke is bulky, highly perishable, and difficult to transport and market. Although coffee is far easier to transport and market, maintaining high-quality standards remains a challenge. As temperatures rise, and if shipments remain stuck in transit due to challenges in the harbor at Mombasa, the loss of quality might become significant.

As stated earlier, Arabica coffee is Uganda's commodity most vulnerable to climate change. The literature reviews clearly highlight potential for a significant reduction in the viability of Arabica coffee in the face of rising temperatures. Not only do erratic precipitation, due to continued high inter-annual variability, and rising temperatures reduce productivity, they substantially increase the likelihood of diseases and pests because both multiply more quickly under warmer conditions, and are able to migrate into higher altitudes where their presence was previously unknown.[20]

The potential impact on Robusta coffee is more uncertain. While the "gloom and doom" predictions of the earliest efforts at crop modeling for Robusta coffee (Simonett, 1989)[21] have been thrown into serious question, the extent to which rising temperatures may reduce production is still not well modeled. Robusta can grow in much warmer temperatures than have previously been experienced in Uganda largely because Robusta in Uganda grows at a higher altitude than elsewhere in the world. Rising temperatures are likely, however, to result in increasing pest and disease pressure (see Annex C), which may have significant impact.

For matooke, researchers have concluded that in the lowland tropics—such as coastal West Africa and parts of Latin America—where temperatures are already extremely high, even slight temperature increases could damage matooke production or eliminate it altogether. In cooler areas like Uganda, increased temperatures are expected to favor matooke production, partially offsetting losses elsewhere in the world. Again, the potential offsetting impact of increased pest and disease incidence is not well understood. This benefit also assumes a significant investment in research and technology to support a shift in production to more favorable areas and/or the introduction of better-adapted varieties.

Compared to annual crops, perennial tree crops/plants such as coffee and matooke pose a more strategic challenge with respect to climate change than do annual crops. Not only do perennial tree crops/plants require a longer lead time to adapt to a changing climate; because these are important

20 This is particularly true for the coffee nematode, coffee leaf miner, the coffee berry borer and for nematodes, weevils, and Sigatoka, fungus in matooke.

21 Simonett essentially predicted a loss of most of Uganda's Robusta coffee production with a 2° C change in temperature.

cash crops, their presence—or lack thereof—also has a major impact on the national economy.[22] For coffee, a number of years must pass before changes made by farmers and business partners yield results. The climate will have changed during that time, adding a considerable level of anxiety and uncertainty to the equation.

The long-term impact of climate change on coffee and matooke production depends on production practices. For example, researchers increasingly recommend that coffee be intercropped with matooke or grown under shade to mitigate the impact of rising temperatures and reduce moisture loss. The development and adoption of climate-smart intercropping systems, which incorporate agroforestry, improved soil fertility management, moisture retention, and disease management, will be critical to the future production of both crops in the face of continued climate stress.

A recent study by the International Institute of Tropical Agriculture (IITA), for example, has shown that intercropping trees and matooke with coffee can generate up to 50 percent in additional income without reducing coffee yields. This additional yield could help farmers diversify their income, minimize their risks, and improve their food security. Earning an income from intercropped matooke also encourages farmers to prune and replant aging coffee trees, because this strategy also compensates for the loss of income when coffee trees are still immature. In addition, the shade helps to reduce temperatures and moisture loss and mitigates the effects of climate change by capturing CO_2 from the air. Finally, matooke also provides mulch, contributing to improved soil quality and carbon sequestration.

- **Maize and beans.** Maize and beans are New World crops introduced to East Africa late in the nineteenth century and are often intercropped with each other. Uganda is a surplus producer and important exporter of both commodities to other countries within the region. Because of the ease with which they can be stored and prepared, beans and maize flour form the basis of institutional feeding in Uganda for schools, hospitals, prisons, armies, and emergency food relief. As a result of the unusual diversity of Ugandan production and diet (as well as a traditional local preference for matooke, coarse grains, and root crops), however, per capita consumption of maize is considerably less than that of most of eastern and southern Africa, where it is the primary staple.

  Many households (more than 1.5 million) throughout the country produce maize and beans. Maize is grown almost equally during both seasons, and farmers tend to plant beans during the second season—especially in the west of the country. Most farmers sell a significant proportion of their maize,[23] but because the cultivated area is small (averaging less than 0.5 ha for maize and 0.22 ha for beans) and yields are low, the quantity sold per household is limited. Farmers allocate a greater proportion of beans for home consumption but sell approximately one-third of the crop on average.

  Marketing channels include many layers of petty traders involved in the aggregation and bulking of produce from small farmers for onward sale to larger traders. The value chain for maize is longer because of the large numbers of export traders and small-scale local processors.

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[22] Coffee had historically been the "engine" of the Ugandan economy, providing over 80 percent of the country's export earnings through the 1970s and 1980s. Coffee's share has since fallen to less than 20 percent of the export portfolio, as other nontraditional exports have expanded. The volatility of international coffee prices is another challenge, discussed in more detail in Annex D.

[23] Nearly 100 percent of traditional cash crops—coffee, tea, and cotton—are sold. Maize falls into the next category and is produced for sale (41 percent sold), while other crops in this category include soybeans (64 percent), rice (55 percent), and Irish potatoes (41 percent).

Maize and beans can both be produced under a wide range of climatic conditions and are not likely to be significantly affected by predicted temperature changes. The greatest impact of climate change on these crops is due to continued high inter-annual variability and amount of precipitation. Maize is greatly affected by short-term water stress or hail, while beans in particular develop significant fungal and viral diseases in the event of excessive rainfall during critical periods. Declining soil fertility and structure greatly exacerbate the problem by reducing the capacity of soil to retain water, thus making nutrients less available to the plants.

Farmers typically sun dry their crops, often on the bare ground. Post-harvest storage losses are high due to pests and decomposition. The maize export market is particularly threatened by the presence of aflatoxin contamination, and the problem will likely be greatly exacerbated if the predicted increases in the traditional dry season precipitation materialize. The presence of precipitation during this period means that traditional sun drying of grains may result in degraded grains/seeds for storage and an increase in diseases/fungi such as aflatoxin, which thrive in moist conditions.

- **Rice.** Introduced into Uganda fairly recently and originating from Asia, rice has undergone tremendous expansion in recent years as a result of the former Vice-President's rice promotion initiative. Since 1990, rice production has quadrupled and become a significant cash crop in areas previously dependent on cotton. More than 100,000 Ugandan households now produce the crop.

  Growing conditions in Uganda are not optimal for rice production largely because of high rainfall variability and a lack of closely controlled irrigation systems. Only 2 percent of the total rice land in Uganda is irrigated wetland, while 53 percent is rain-fed wetland, and 45 percent is dry land. The production of highland rice faces significant water stress due to intermittent short-term dry periods, while rain-fed lowland rice, which has increasingly intruded into Uganda's extensive wetlands, is frequently subjected to unseasonal flooding. On the other hand, temperature increases do not pose a significant threat to rice production because existing varieties prefer warmer climates. Climate change is, however, expected to continue to experience unpredictable precipitation and an increase in extreme events that result in flooding and hail damage. Rice is also susceptible to considerable disease stress. Two major rice diseases (blast and bacterial leaf blight) are significantly aggravated by adverse weather conditions that affect temperature, air humidity, and soil moisture status, posing a threat to the crop.

  The value chain for rice is also complicated by the need for irrigation services, as well as drying, hulling, and polishing. The good news is that processing capacity has steeply increased in recent years, as volumes became more attractive to investors. Urban populations prefer rice because of the ease of storage and cooking. Although Uganda has historically been a net importer of rice, increased production has reduced the foreign exchange bill in recent years. Rice exports have risen sharply since 2003, with Uganda exporting lower-quality broken rice, offsetting some of the high-quality long grain rice that is still imported for higher income customers. Uganda now produces more than 80 percent of its net annual rice consumption. The question is whether this situation is sustainable without considerable investment in irrigation infrastructure.

- **Sorghum.** Sorghum, a grain that originated in north East Africa, is characterized by 30,000 varieties, all of which have different production requirements. In Uganda, more than 600,000 households produce sorghum, making it the second most important grain after maize.

Sorghum, unlike other cereal crops, can be grown in relatively dry areas - low-rainfall arid to semi-arid. It is also well adapted to a wide range of precipitation, temperature levels, and altitudes. Compared to other major cereal crops, such as maize and rice, sorghum is more tolerant to adverse growing conditions because it efficiently photosynthesizes light and requires little in the way of water and nutrients.

A number of improved early maturing sorghum varieties require less than two months of rainfall to produce grain. The species is genetically diverse, with preferred varieties for different environments and different uses. Moreover, while the potential yield for sorghum is significantly lower than that of maize, the possibility of complete crop failure is also less.

Despite the crop's resilience, however, increased temperatures, combined with reduced precipitation, are also likely to lead to the proliferation of striga, a parasitic weed that reduces yields by sucking and diverting water and nutrients from the plant's roots. The parasite is also more prevalent in areas with degraded soils especially those that are drought-prone. Higher temperatures may also promote smuts and stem borers, and lead to epidemics of leaf blight—although the extent of the threat is still unclear.

One of the most interesting developments with respect to the sorghum value chain is the introduction of sweet sorghum grown under contract for the brewing industry. This new crop holds the potential to offer farmers new opportunities for commercial production with a known and reliable market structure. In contrast with the tall, long maturing varieties of sorghum, traditionally grown for food and local brewing (which can take up to 170 days to mature), the sweet varieties mature in just 90 to 110 days and are much shorter in stature, so are less prone to becoming top heavy and collapsing. Specific information on the relative impact of climate change on these particular varieties is not yet available. Nevertheless, experts agree that longer maturing varieties have the potential to offer farmers higher yields under optimal conditions, but that shorter maturing varieties can also do well even when the rainfall season is limited. It is important to note, however, that sweet varieties are also more attractive to birds than traditional varieties.

- **Sweet potatoes and cassava.** Sweet potatoes and cassava are New World root crops introduced to Uganda early in the pre-colonial period. Uganda's climate is well suited to their production. Colonial by-laws enforced mandatory planting of cassava as a famine reserve crop; contributing to the wide spread prevalence of the crop throughout the country. Both crops are grown primarily for food security. Cassava and some varieties of sweet potatoes have the advantage of remaining palatable for long periods, even when left unharvested in the ground. Only about 22 percent of the cassava crop is sold, while sales of sweet potato are even lower, at 12 percent. While cassava can also be dried and stored as chips or flour, sweet potatoes are highly perishable; and the dried form is not popular with consumers. It is primarily consumed on the farm or within the immediate rural market catchment area. Both crops have the reputation of being a "poor man's food," although consumption has increased due to the rising cost of living. Production areas along the major transportation routes in eastern and central Uganda feed the supply chain into the major urban areas.

  Sweet potatoes are a short-duration crop that can be produced in a single season. Some varieties will keep underground for up to six months, but others for only a month or two. Farmers generally stagger planting by growing a number of varieties with different characteristics to spread risk and to ensure availability throughout much of the year.

Cassava is a longer-term crop and requires six to 24 months to achieve maturity, depending on the variety and growing conditions. It can remain underground for up to 18 months after maturity, while maintaining its freshness. This makes it an ideal crop for areas facing intermittent food shortages or political unrest. Once harvested, however, its high water content means it will quickly spoil and it must be consumed or processed immediately—usually close to the point of production. Unlike West Africa, which produces high cyanide varieties of cassava processed into semi-precooked fast foods for the urban market, in Uganda the sweet varieties (low cyanide) are preferred. These are widely consumed in fresh form or dried in simple chunks to later grind into low quality flour that is usually blended with either millet or sorghum.

Both crops can grow well at temperatures higher than those that could result from climate change over the next 30 years. Productivity is fairly resilient, and although yields in Uganda are significantly lower than that achieved by intensive farming in Asia, there is little chance of complete failure due to climate variability. For this reason, cassava is often touted as the food security crop of the future—especially because of its potential for a wide range of industrial uses, such as for starch and bio-ethanol. The reality, however, is that cassava in Uganda is not yet widely used for industrial processing, while its bulk and post-harvest perishability reduce its marketability. It is also not as nutritious as other popular food security crops.

While cassava and sweet potatoes tolerate climate change relatively well, both crops are also highly vulnerable to disease and pests. Because they multiply through vegetative propagation, access to clean planting materials is always a challenge. In the 1980s, cassava was almost completely wiped out in Uganda by a virulent form of African Cassava Mosaic Virus; the resistant varieties introduced to combat the epidemic quickly succumbed to a subsequent epidemic of Brown Steak Virus. Sweet potato production is also significantly impaired by endemic viruses, which spread and proliferate during the transfer of planting material.

Considerable development assistance has been invested in the identification of resistant varieties and the establishment of rapid multiplication and distribution systems for virus-free planting materials with strict quality control. Nevertheless, much work still needs to be done. Little is known about the possible interaction between these diseases and climate change, but the increasing unpredictability of precipitation and extreme events could be a significant challenge to the production and preservation of planting materials during the dry season. Without access to clean planting material, these crops can become highly vulnerable.

The following table compares areas of identified vulnerability according to crop.

TABLE 2. COMPARISON OF THE EXTENT OF CLIMATE-RELATED VULNERABILITY BY CROP

Vulnerability	Coffee*	Matooke	Maize	Beans	Rice	Sorghum	Sweet Potatoes	Cassava
Rising temperature threatens suitability for production	+++	++	++	+	+	+	+	0
Falling soil fertility reduces yields and makes crop more vulnerable to climatic stresses	+++	+++	+++	++	++	++	+	+
Poor moisture retention capacity of soils increases vulnerability to precipitation variability	+++	+++	++	++	++	+	+	+
Pests and diseases increasing with rising temperatures	+++	+++	+	++	++	+	+	-
International prices increasingly volatile as a result of climate change impacts on supply	++	0	++	0	0	0	0	0
High temperatures and unseasonable rain promote rapid spoilage and threaten quality	+++	+++	++	+	0	0	+	+
Rising international concern over carbon footprint may threaten demand for exports	+++	++	0	0	0	0	0	0
Shortages of disease-free planting materials, exacerbated by unreliable precipitation	+++	+++	0	0	0	0	+++	+++
Crop is perishable. Extreme precipitation and flooding make transport more costly & difficult	++	++	+	+	+	+	++	++
Increasing variability of precipitation and extreme events threatens suitability for production	++	++	+++	+++	+++	+	+	+

Key: Relative impact of climate change on various aspects of vulnerability by crop:

+++ Highly Vulnerable
++ Moderately Vulnerable
+ Limited Vulnerability
0 Not Affected

**Note: Threat of rising temperatures is much more acute for Arabica coffee than for Robusta*

2.2.2 HOUSEHOLD SENSITIVITY TO CLIMATE CHANGE

The livelihood analysis is based on empirical data gathered at the field level. Under the vulnerability framework employed here, the impacts of climate variability and change are typically experienced at the household level—either directly through household production systems or indirectly through the commodity value chain.

All households within the same geographical area are equally exposed to a stressor, but the levels of sensitivity and adaptive capacity vary from one household to another. To capture this individual variation, a quantitative survey was designed to classify typical groupings of sensitivity and adaptive capacity and reveal variations in patterns based on household characteristics and decision making across all of the groups surveyed. At the same time, a qualitative assessment was conducted to determine the more detailed perceptions of change in climate stresses and the corresponding behavioral responses. In this way, the outcomes of the qualitative focus group sessions provide in-depth insights into the patterns emerging from the quantitative work. The following sections describe the sampling strategy, data collection, and analysis that guided this methodological approach.

Sampling Strategy
Uganda is a large and highly diverse country, and the first methodological challenge was to define the population in a statistical sense. Based on discussions with the USAID/Uganda Mission and a review of government documents, the sampling frame was constructed around six carefully selected agricultural districts, all of which share the following characteristics:

- They are targeted districts under the USAID Feed the Future Initiative.
- They have agro-ecological variability that captures the priority crops for both the GoU and USAID.
- They are close to meteorological stations that have a credible time series of precipitation and temperature data.

Following the implementation of the above strategy, the sampling frame identified the districts of Gulu and Lira (central north), Luweero and Mbale (center and central east), and Isingiro and Kasese (south and west). All six districts are characterized by significant variability with respect to agro-ecological characteristics, cropping and livestock systems.

Using available census data, it was determined that five of these districts share a similar population size, but Kasese supported significantly more households. The sample size was 120 households for each of the five districts and 200 households for Kasese— for a total of 800. The sample size decision was based on traditional criteria for external validity (control of sampling error), time, resources, and logistics. The sampling survey itself, once the districts were selected, involved a random two-stage cluster strategy in which two sub-counties were selected at random from each district; three villages from each sub-county (six villages total), and 20 households from each village, for a total of 120 households. In the case of Kasese, three sub-counties and 10 villages were selected for a sample size of 200 households.

For the qualitative focus group component, a more specific sampling procedure was followed. In each village, two FGDs were conducted separately, one with men and one with women, generating a total of 80 FGDs. Each group consisted of between eight and 20 participants who were identified with the assistance of local (informal) leadership and chosen because they represented different socioeconomic groups residing within the community. A topical outline was used to structure these informal discussions, and each session included at least one facilitator and one recorder. These outlines covered local perceptions of changes in climate over the previous 20 years, the impact of severe weather events on agriculture and socioeconomic well-being in general, and responses to perceived climate change (see Annex A for FGD topic outlines).

Data Collection
A local Ugandan firm, the Nordic Consulting Group (NCG), undertook the collection of data, both quantitative and qualitative. The Tetra Tech assessment team trained a team of 42 field workers, including enumerators, focus group facilitators, and supervisors in Kampala. The team then dispatched six teams—one to each district. A Tetra Tech assessment team member accompanied and worked with the fieldworkers in each district for at least one week. Data collection was completed over a period of six weeks, and then data from the survey questionnaires were entered into SPSS format for analysis.

The survey data were organized around a livelihoods approach (see Annex B for the questionnaire). Researchers conducted household interviews to document what types of assets (human, natural, physical, economic, and social capital) were mobilized and allocated through household decision-making strategies; they then assessed the outcomes of these strategies (e.g., food security, education, shelter, health, etc.). For each household, researchers recorded shifts in decision making and asset levels to capture the possible impact of environmental factors. The FGDs probed more deeply into the reasons for such changes at the village level.

Analysis

A major objective of the quantitative survey was to assess the degree to which households are vulnerable to climate change. Measuring vulnerability is always challenging, and many attempts have been made to create relevant indices. In this analysis, however, a vulnerability variable was developed using principal components and cluster analysis techniques. A principal component analysis (PCA), also referred to as a factor analysis, identifies correlations among input variables and determines the presence of an implied factor within the correlation clouds. For this analysis, the input variables were those that would either be directly affected by climate—such as the value of all crops and animals sold, or the food consumption score (FCS)—as well as those that reduce sensitivity such as the value of off-farm income, of loans, and the asset (wealth) index.

The PCA determined that the underlying factor was best determined by crop sales, off-farm income and the asset index. The underlying factor, which was interpreted as a vulnerability variable, was then clustered into three natural groupings. As expected, the majority of observations fell into the "most" vulnerable group. For analytical purposes therefore, the two upper "least" vulnerable groups were clustered together. This left a vulnerability category variable with 76 percent of the sample in the most vulnerable group and the rest in the least vulnerable group. The PCA approach to measuring comparative vulnerability levels is well known and widely used in vulnerability assessments.

Several other key variables were created during this analysis. Within a livelihoods framework, education is an important measure of the quality of human capital. The questionnaire included information about the educational levels of every member of the household above five years of age. A simple transformation then assigned to each household member a "one" if the level of education was consistent with the age group; if not, a "zero" was assigned. For those members over 18 years of age, a completed primary education was assigned "one" and a completed secondary education (or above) was assigned a "two." These scores were then aggregated as a household mean (ranging from zero to two), thereby providing a unique number representing the household's investment in education.

A second variable used in the analysis was the "asset index". The questionnaire contained a list of production and consumption assets; the former category included such resources as farm equipment, etc., with the latter category including cell phones, vehicles, and furniture. Each item was assigned a weight relative to the least valuable item, and this number was then multiplied by the number of assets in each category to generate a number for each household. The asset index score is rather imprecise in terms of actual absolute household wealth, but for a large sample size, it allows for a fairly robust assessment of the relative wealth of all surveyed households.

The analysis also used the FCS, a widely accepted FAO measure of dietary diversity. A section of the questionnaire collected seven-day recall data that examined the diet of the households surveyed according to food groups (grains, oils, vegetables, meat, etc.). Standardized weights were applied to each food group and then multiplied by the number of times each item from the designated food group was consumed over the seven-day period[24] and then summed to produce a household value. Along with the

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[24] See World Food Program manual for further information http://documents.wfp.org/stellent/groups/public/documents/ena/wfp196627.pdf.

asset index, the FCS is an effective technique for measuring the relative value for diet from one household to another.

As stated above, the PCA analysis assigns each household to either the "most vulnerable" or "least vulnerable" category. The distribution of households between these two categories varies from one district to another, with the northern districts, for example, displaying a larger percentage of most vulnerable households. To understand differences between vulnerable households it was possible to create a set of "household livelihood types (HLTs). Twelve HLTs were established based on vulnerability classification (most or least); two—a least and most vulnerable HLT category, for each district. The value of this classification is that it permits a finer analysis of sensitivity and adaptive capacity, the two key factors that explain the nature of vulnerability in Ugandan agriculture.

Household Sensitivity to Climate Change

In this vulnerability framework, sensitivity is defined as the immediate impact upon households of exposure to climate change and climate variability. The relationship between exposure and sensitivity is complex; climate change resets environmental conditions, which in turn determine crop productivity, which in turn affects the livelihood systems that grow those crops. The livelihood stresses from exposure to climate variability can occur as either slow or sudden onset. Changes in moisture availability and biome conditions usually occur gradually, appearing in the form of increased aridity or altered distribution of rainfall, new patterns of pest infestation, and variation in plant species composition. On the other hand, severe storms (e.g., events with high winds, hail, and heavy rainfall) may precipitously wipe out crops, destroy trees, cause flooding, and reduce structures to rubble. The most vulnerable households are those whose livelihoods most directly suffer these impacts (the measure of sensitivity) and are less able to rebound over time (the measure of adaptive capacity). Least vulnerable households are those whose livelihoods are able to buffer the immediate impact of such events and recover in a timely fashion—ensuring that the farming system itself will remain viable.

This section builds upon the crop sensitivity results presented above, since the direct impact of exposure to climate change for households is determined by their relative dependence on these key crops. Within the livelihood framework, however, the impact of climate on crops may be mitigated by how much the household depends upon that particular crop for its well-being. For example, availability to climate-neutral assets may permit the employment of effective coping strategies. Accordingly, the section begins with an analysis of the level to which the different HLTs are directly affected by crop sensitivities, then the analysis shifts to the underlying capacity of these households to absorb the climate shocks over the short run and without irreversible damage to the livelihood system.

The climate analysis above suggests that climate change will present itself in the form of higher temperatures and changes in the December-February rainy season. In the case of coffee and matooke, for example, these changes could alter suitability in areas currently under cultivation and potentially extend their range into other areas.

Based on information elicited in focus group discussions, farmers perceive changes related to more severe storms, untimely rains, longer dry periods, and increased pest infestation, all of which can interrupt the normal biological cycles of flowering and production, resulting in lower yields or catastrophic crop losses. These climate related stressors—both current and projected—define the nature of household exposure to climate change.

Table 3 characterizes the sensitivity of different household livelihood types as a function of their relative reliance on different crops. The two indicators of such crop dependence are the percentage of households within each category that produced each crop during the previous year and the percentage of the total farm production volume (in kilos) that each crop represents. Table 4 presents how important a specific crop is in terms of farm income and total household revenue. These four indicators—direct dependence on the crop and the contribution of the crop to overall household economy—provide reliable estimates of direct impact of climate change on a given household. Below, the analysis examines core characteristics of the HLTs to assess the capacity of households to absorb the immediate impacts.

TABLE 3. SENSITIVITY TO CLIMATE CHANGE, BY CROP AND BY HOUSEHOLD LIVELIHOOD TYPE

DISTRICTS	**Gulu**		**Lira**		**Luweero**		**Mbale**		**Isingiro**		**Kasese**		**Total**	
Vulnerability Level	Most	Least	Most	Least	Most	Least	Most	Least	Most	Least	Most	Least	**Most**	**Least**
Matooke % Producer HHs	0	0	0	0	28	41	15	22	95	97	56	11	**21**	**32**
% of Total Production	0	0	0	0	57	35	49	55	80	78	72	49	**72**	**62**
Coffee % Producer HHs	0	5.3	0	0	27	29	37	52	3	8	48	78	**20**	**40**
% of Total Production	0	22	0	0	22	32	16	14	3	6	44	38	**31**	**32**
Maize % Producer HHs	16	63	57	56	68	95	98	100	59	72	47	53	**56**	**71**
% of Total Production	29	17	28	20	29	31	38	33	8	6	38	33	**30**	**26**
Beans % Producer HHs	65	95	69	83	89	81	100	96	86	82	69	81	**78**	**84**
% of Total Production	23	28	12	10	25	13	22	18	8	6	16	15	**18**	**14**
Rice % Producer HHs	10	16	13	22	0	0	0	0	0	0	0	0	**4**	**3**
% of Total Production	33	40	29	28	0	0	0	0	0	0	0	0	**30**	**33**
Cassava % Producer HHs	15	32	43	44	22	22	54	44	35	56	41	52	**35**	**44**
% of Total Production	22	17	7	78	33	30	34	33	7	5	36	27	**39**	**26**
Sweet Potato % Producer HHs	6	5	10	11	23	50	10	11	28	41	2	3	**15**	**21**
% of Total Production	44	1	15	5	36	34	33	15	7	6	29	36	**26**	**21**
Sorghum % Producer HHs	47	42	9	0	1	2	1	0	5	5	2	1.4	**11**	**6**
% of Total Production	42	26	22	0	29	14	30	0	5	2	36	0	**36**	**19**

TABLE 4. INCOME SENSITIVITY TO CLIMATE CHANGE, BY CROP AND HOUSEHOLD LIVELIHOOD TYPE

DISTRICTS	Gulu		Lira		Luweero		Mbale		Isingiro		Kasese		Total	
Vulnerability Level	Most	Least	Most	Least	ost	Least	Most	Least	Most	Least	Most	Least	**Most**	**Least**
Matooke Share/Crop Income (%)	0	0	0	0	5	9	8	20	66	68	5	2	**43**	**40**
Share/Tot HH Income (%)	0	0	0	0	4	3	2	8	38	26	0.8	0.6	**25**	**16**
Coffee Share/Crop Income (%)	0	0	0	0	76	71	77	67	36	34	85	78	**80**	**73**
Share/Tot HH Income (%)	0	0	0	0	47	28	44	25	31	28	47	33	**46**	**30**
Maize Share/Crop Income (%)	13	23	25	20	6	15	14	6	8	6	23	15	**15**	**13**
Share/Tot HH Income (%)	8	4	15	13	3	4	7	0.7	5	3	13	6	**9**	**4**
Beans Share/Crop Income (%)	35	30	3	26	15	10	7	16	20	14	9	11	**14**	**15**
Share/Tot HH Income (%)	16	6	1	12	9	2	4	1	10	7	4	4	**7**	**5**
Rice Share/Crop Income (%)	50	38	53	34	0	0	0	0	0	0	0	0	**30**	**33**
Share/Tot HH Income (%)	24	24	33	11	0	0	0	0	0	0	0	0	**29**	**16**
Cassava Share/Crop Income (%)	18	14	8	8	2	12	15	22	5	3	17	10	**12**	**10**
Share/Tot HH Income (%)	8	3	4	2	0.5	6	10	0.8	3	2	8	5	**6**	**4**
Sweet Potato Share/Crop Income (%)	9	0	0	0	7	1	5	0	5	0.8	0	0	**5.3**	**1**
Share/Tot HH Income (%)	3	0	0	0	3	0.5	2	0	0.9	0.4	0	0	**2**	**0.4**
Sorghum Share/Crop Income (%)	19	10	60	0	100	0	0	0	8	0	0	0	**23**	**7**
Share/Tot HH Income (%)	12	2	27	0	1.6	0	0	0	2	0	0	0	**12**	**1**

Matooke. In the case of matooke, identified as a crop that is moderately vulnerable to climate change, the three districts of significant production in order of importance are Isingiro, Luweero, and Mbale. In Isingiro, matooke is the mainstay of the household economy—it is grown by virtually every household. It contributes two-thirds of all agricultural revenue and 38 percent of total household income for the most vulnerable households and 26 percent for the least vulnerable. In Luweero, 30 percent of the most vulnerable households and 40 percent of the least vulnerable households are matooke producers, but the contribution of matooke to overall agricultural income is less than 10 percent and to total household income less than 5 percent. A similar pattern holds true for the Mbale producers, where more of the least vulnerable households grow matooke, but its economic contribution is low. It is likely that in these two districts, matooke is mostly directed at household consumption rather than the market; thus, its value must be assessed in terms of household food security.

Coffee. Coffee is highly vulnerable to climate change. The three most important coffee-producing districts (in descending order) are Kasese, Mbale, and Luweero.[25] For Kasese, almost one-half of the most vulnerable—and 78 percent of the least vulnerable households—have coffee trees; and coffee accounts for 44 percent and 38 percent, respectively, of total farm production. The sales of coffee contribute to around 80 percent of agricultural income and 46 percent of total household income. It is relevant to note that coffee sales are less important for the least vulnerable Kasese households (33 percent of total household income), which are more diversified both in agriculture and outside agriculture.

In Mbale, more than one-third of the most vulnerable and one-half of the least vulnerable households produce coffee, which contributes about 15 percent of total crop production by weight. In terms of its economic value to the household, coffee sales account for 77 percent and 67 percent, respectively, of the total agricultural income of most and least vulnerable households, and 44 percent and 25 percent of total household income for these same households. A similar pattern is discerned in Luweero. More of the least vulnerable households grow coffee, and it represents a major part of total farm production. But the least vulnerable households are less dependent on coffee as a contributor to the household economy.

Maize. Maize constitutes an important part of the overall cropping pattern in Mbale, Luweero, Isingiro, Lira, and Kasese, in descending order. Virtually all households in Mbale grow maize, where that crop represents more than one-third of total farm production. In Lira and Isingiro, most households grow maize, but its share of total crop production appears to be much lower.[26]. In Luweero, maize production is more prominent among the least vulnerable farmers. While maize is widely produced, it is mostly consumed within the household and is not a significant contributor to agricultural or household income except in Lira and Kasese, where maize sales account for somewhat less than 15 percent of household income. In these districts, maize sales are more critical for the most vulnerable households. In Luweero, Mbale, and Isingiro, maize is a primary contributor to household food security. In Luweero, where production is also widespread, maize contributes less than 5 percent to the household income. With respect to the most vulnerable households, most of the maize is consumed within the household (in fact, only 7 percent was reported as sold)—a pattern that holds throughout all of the producing districts.

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[25] In Luweero the coffee produced is Robusta. In Mbale it is Arabica, while Kasese produces both depending on the altitude.

[26] Production was measured in kilos, so it is possible that heavier crops (although produced in lesser quantity) weighed more (e.g., matooke).

For the least vulnerable households in Luweero, the small contribution to overall income is most likely due to the relatively larger contribution of off-farm income. In Mbale, maize constitutes approximately one-third of the total production based on weight and is a relatively important cash crop for the most vulnerable farms. For the less vulnerable group, however, the value of coffee to overall household income has a much greater proportional weight. In Kasese, the value of maize is again more pronounced for the most vulnerable group because of the predominance of coffee for the least vulnerable farmers. In other words, vulnerable groups living in a maize-producing district tend to be more sensitive to the impact of climate change because they are dependent on the crop both for food and as a relatively important source of income for cash-strapped households.

Beans. Beans are produced and consumed across all six districts and considered a moderately vulnerable crop. Many local varieties do not respond well to periods of aridity and are particularly susceptible to post-harvest losses from increased moisture. Around 80 percent of households reported bean production in the previous year, and beans constituted 18 percent and 14 percent, respectively, of the total crop production of the most vulnerable and least vulnerable households. In terms of these indicators, Gulu shows the greatest level of dependence on bean production. This conclusion is corroborated by the share of bean sales in both total agricultural and household incomes for the most vulnerable households. In Lira, the least vulnerable households are more involved in beans sales, while in the other districts, the most vulnerable households receive a greater portion of income from beans. Overall, in Gulu and Lira, over 70 percent of bean production is sold. Since beans produce relatively rapidly, they represent a crop that is both widely consumed but can be sold to generate cash when needed.

Rice. Rice is produced only in Gulu and Lira in this sample, and is primarily a cash crop.[27] Ten percent of the most vulnerable households and 15 percent of the least vulnerable grow rice in Gulu, while 13 percent of the most vulnerable and 22 percent of the least vulnerable in Lira are rice farmers. Income from rice sales is half of all crop income for the most vulnerable households in both districts and constitutes 24-33 percent of household income for this group. Rice sales represent one-third of crop income for the least vulnerable, and 10-24 percent of total household income.

Cassava. Cassava is important as a food crop, and is grown primarily in Mbale, Isingiro, Kasese and Lira. In Lira, cassava accounts for more than three-quarters of total crop production, but in Isingiro, it constitutes less than 10 percent of the total farm production, suggesting the amounts produced are small and mostly for home consumption. In the other producing districts, around half the households report cassava production, and its share of total production is around one-third. While most cassava is consumed within the household, it is a significant cash crop in Gulu, Mbale and Kasese, where it accounts for 8-10 percent of total household income. Cassava is vulnerable to climate change, primarily in terms of diseased planting material caused by increased temperature.

Sweet potato and sorghum. Sweet potato is grown in 20 percent of households, mostly those in Luweero and Isingiro. Fewer of the most vulnerable households grow sweet potato; however, for those that do, this crop represents a larger share of household income (albeit small) when compared with least vulnerable households. These patterns suggest that sweet potato is cultivated as an easy-to-grow crop that is mostly consumed but can also be sold by the most vulnerable households to meet cash

[27] This is primarily upland rice, but Lira does have one irrigation scheme.

needs. Sorghum is also grown primarily in the north and is most important to Gulu households. The sales of sorghum constitute more than 10 percent of the income of most vulnerable households. In Lira, only the most vulnerable households grow sorghum. While only 8.8 percent of these households grow sorghum, this crop constitutes 60 percent of their total agricultural sales and over 27 percent of total household income. In Lira, sorghum is primarily grown as a cash crop because the major variety grown is the new sweet sorghum produced for breweries.

Conclusions

It can be concluded that in the districts more suited to the cultivation of maize, matooke, and coffee production, the most vulnerable households currently engage in the production of all three key crops, although they tend to grow less than their least vulnerable counterparts. With respect to maize and matooke, most vulnerable producers tend to consume a greater share of their total production, thus selling less compared to the least vulnerable group.

The importance of market sales of these commodities to the most vulnerable group is significantly more important to the household economy because of relatively fewer sources of off-farm income. Beans and cassava are staple food crops in most districts, but among the most vulnerable households, sales of both crops contribute significantly to household income. Rice is a cash crop in Gulu and highly important to both vulnerability groups, while sorghum and cassava are locally important because they provide both food and cash for the most vulnerable farmers.

In combining the characteristics of the different HLTs with their respective levels of reliance on specific crops, an overall risk profile of the vulnerable groups begins to emerge. The sensitivity of the most vulnerable groups can be attributed to the fact that they are cash poor with restricted access to climate-neutral sources of income; they tend not to have savings or household wealth. Thus, any change in the availability of food (through production variations or crop losses) or in market sales can severely disrupt the financial viability of these farm households, which represent approximately 70 percent of the total population of the six districts. With such narrow risk thresholds, any climate-related change in crop sensitivity will have a major negative impact on the vulnerable population as a whole.

How Households Cope over the Short Run

The previous discussion sought to assess the relative sensitivity of households to climate-forced changes in key crops. Households, however, are able to absorb the immediate impact of climate shocks or slow onset events by drawing upon their livestock and other forms of household wealth or by reallocating resources in more climate-neutral ways. This section presents the characteristics of households that make them more or less sensitive to crop production stresses. Following a livelihoods approach, the results are presented as a set of indicators that constitute the household stock of human, natural/physical, financial and social capital. It also includes an indicator of food security, which helps to understand the urgency of climate impacts on crop systems, and a separate analysis of gender-related information to improve understanding how men and women cope.

Livelihood Assets

Human capital. Table 5 summarizes the key characteristics of the HLTs according to livelihood assets and outcomes. General demographic patterns can provide insights into the quantity and quality of human capital. For example, household size (approximately seven for this sample) does not vary between districts; but family size, with a higher ratio of producers to non-producers, is significantly larger in the least vulnerable households (except in Luweero).[28] In rural areas where farming is labor dependent, the availability of household labor is considered an asset. Moreover, the dependency ratio is consistently lower in the least vulnerable families—which translates to fewer non-productive family members supported by productive family members.

With the exception of Kasese, a significantly higher proportion of female-headed households were represented in the sample. As a whole, these households tend to be more labor-scarce and asset-poor than jointly managed households. In this sample, widows—many of whom had been affected by extended conflict and/or HIV/AIDS—managed 60 percent of the female-headed households. Using the measure of household educational "investment," clear differences between the vulnerability groups were evident, which means that those who are least vulnerable include a higher number of educated members and children who are in school. If these characteristics reflect the inherent human capital pooled in these households, it is possible to conclude that the least vulnerable households are larger—with more producers relative to non-producers—and are more educated overall.

Natural and physical capital. Key variables for natural and physical capital include the area of cropland planted in 2011; ownership of cattle, sheep, and goats; and wealth accrued in productive and consumable assets. Table 5 shows that throughout the six districts, farm size is small, averaging less than three acres for the most vulnerable households and somewhat more than four for the least vulnerable farmers. However, significant differences are apparent among districts. In Gulu, Isingiro, and Kasese, farms are relatively larger; in Mbale, the small land size reflects a structural scarcity of farmland. In Uganda, land ownership is common in most districts, but access through customary land rights distributed by locally acknowledged chiefs is also widespread. Additionally, a number of households possess land that is not being farmed (e.g., that is forested, pasture, and/or fallow). In Gulu, Isingiro, and Kasese, land ownership far exceeds farm size. This suggests that these households also own fallowed or forested lands. In Mbale, however, the farm size is significantly smaller with diminishing land resources that are forested or fallowed.

Animals—particularly cattle, sheep, and goats—provide an immediate buffer to climatic shocks and stresses that can be sold or managed to compensate for crop loss. Because cattle are worth more than other livestock, cattle ownership is limited to wealthier households. Only a third of the households surveyed however, reported owning cattle. Lira, Mbale, and Isingiro are districts where more households own cattle. Despite this, major differences were still found between the vulnerability categories. Across all districts, fewer most vulnerable households own cattle. Small ruminant ownership is more prevalent, and in Lira, Gulu, Isingiro, and Kasese, more households own sheep and goats. With the exception of Lira and Mbale, the differences in ownership between the two vulnerability groups are statistically significant. An index of stored wealth available to households—in the form of consumer goods, production assets, transportation means, and number of trees—was calculated along with results, and is reported in Table 5. This index suggests less wealth in Gulu households (an area affected by long-term conflict), but relatively more in Isingiro and Kasese, where several outlier households own tree

[28] This should not be interpreted as an argument for larger household size, but rather as an indicator that many most vulnerable households do not have as much human capital to allocate.

plantations. As is the case with livestock, many physical assets can be sold during times of crisis and can thereby decrease the overall sensitivity of wealthier households to climate stressors.

TABLE 5. CORE LIVELIHOOD CHARACTERISTICS OF HLTS (HUMAN/NATURAL/PHYSICAL CAPITAL)

District	Vulnerability Level	Human Capital				Natural/Physical Capital			
		HH Size	% HH Female	Dependency Ratio	Education Score	Cropland (acres)	Cattle[a]	Sheep/ Goats[a]	Asset Index
Gulu	Most	6.7	33	1.4	.49	3.1	12	49	57
	Least	7.9	0	1.2	.70	3.5	42	68	172
Lira	Most	6.0	25	1.3	.44	2.5	50	64	124
	Least	6.8	17	1.0	.85	3.7	67	67	230
Luweero	Most	5.6	33	1.6	.78	2.1	18	30	107
	Least	5.4	26	1.2	.98	3.1	35	43	204
Mbale	Most	6.6	10	1.2	.77	1.4	42	27	137
	Least	7.3	4	0.9	.85	1.8	74	22	282
Isingiro	Most	6.2	27	1.3	.61	5.6	19	57	288
	Least	6.9	15	1.2	.85	9.4	49	64	2600
Kasese	Most	6.1	17	1.1	.61	3.2	2	60	199
	Least	6.9	16	0.8	.78	3.6	7	74	1812
Total	Most	6.2	23	1.3	.61	2.9	23	49	151
	Least	6.7	15	1.0	.84	4.3	36	59	1476

Key: a = Percentage of households that own cattle and sheep

Financial capital. In Table 6, HLTs are compared in terms of financial and social capital, in addition to overall food security. In this livelihood formulation, financial capital is made up of three income streams: crop sales, animal sales,[29] and off-farm income. The survey results show that more than two-thirds of the most vulnerable households and 84 percent of the least vulnerable report crop sales. Animal sales and off-farm income generation are less common among the more vulnerable households; for those households that did benefit from off-farm income earnings, the average revenue per household is four to eight times lower for the most vulnerable families.

Significant inter-district patterns are also evident. For example, Luweero stands out as a district characterized by a relatively lower reliance on crop sales relative to off-farm income. This district is close to Kampala (an hour's drive away) and enjoys ready access to employment opportunities in the capital. Animal sales are substantial in Isingiro—including for the less vulnerable groups living in Gulu, Luweero, and Mbale. A broad stroke interpretation of these patterns suggests that both vulnerability classes are integrated into commodity markets but is more common among the least vulnerable households.

Markedly more of the least vulnerable households sell animals and engage in off-farm income generation, and the income streams from these sources are much greater for these least vulnerable household

[29] Here only the sale of live animals is considered. Although some households produce an income stream from the sale of animal products, primarily eggs and milk, the information provided by the survey was not reliable and the number of households engaged was very small.

types. The household sensitivity to climate change by crop analysis (Tables 3 and 4) identified which households are more exposed to climate impacts based on key crops such as maize, coffee, matooke, beans, rice, cassava, sweet potato, and sorghum.

Social capital. Despite the challenges inherent in trying to measure it, social capital is considered a determinant of sensitivity during a crisis. Social capital is often thought of as a reserve stock of community resources, which can be accessed at a time of unexpected stressful events. Since social capital is accessed at times of stress, it can be considered a component of sensitivity, and those households that display a larger "stock," in principle have a lower level of direct sensitivity.

In this analysis, two variables were created from the household survey results: one based on the intensity of participation in community-based groups, and the other based on the intensity of giving and receiving reported over the last year. These quantitative responses in both cases were ranked according to three categories (by terciles) to compare them. Thus, from a range of one to three (from low to high participation and low exchange activity), it is possible to derive from Table 6 the relative amounts of social capital enjoyed by the different HLTs.

In terms of participation, the least vulnerable households consistently reported a higher level of participation in community groups such as religious and production associations, labor-sharing, savings, cultural groups, etc. With regard to exchange activity, there is little difference among the vulnerability classes in Gulu, Luweero, and Lira; while in Mbale, Isingiro, and Kasese, the least vulnerable groups engaged more in giving and receiving activities. While it could be hypothesized that the most vulnerable groups received and the least vulnerable gave more, such was not the case. In several districts, a larger proportion of least vulnerable households reported a higher amount of receiving (both money and in-kind benefits, such as food and clothing) from relatives and neighbors. Overall, it appears that least vulnerable households cultivate their social reserves more consistently.

Food security. Finally, one can argue here that food insecurity is a measure of urgency—assuming that a more food insecure household would be the one with less of a margin to negotiate during a crisis period. Again, two variables of food security/insecurity were measured in the household survey—the FAO-based FCS and the number of reported months of inadequate food supplies during the past year (June 2011–May 2012). The FCS is an indicator of diet diversity and is calculated on the basis of a seven-day recall of seven basic food groups consumed within a household, which are weighted according to nutritional value.

In this analysis, the absolute scores are difficult to interpret, but the relative scores indicate a general difference in diet quality between the HLTs. As Table 6 demonstrates, in Gulu, households generally scored lower on diet quality, with no difference between the vulnerability groups. This result might reflect the fact that Gulu is coming out of an extended conflict. In other districts, differences in the scores between the vulnerability groups are apparent, mostly determined by differences in the household consumption of animal proteins (meat, milk, eggs, and fish). The higher scores in Luweero are likely explained in terms of proximity to the food markets of Kampala, which offer a wider array of foods.

TABLE 6. CORE LIVELIHOOD CHARACTERISTICS OF HLTS (FINANCIAL AND SOCIAL CAPITAL, AND FOOD SECURITY)

District	Vulner-ability Level	Financial Capital			Social Capital		Food Security	
		Crop (%)[a]	Animal (%)[a]	Off-farm (%)[a]	Participation Index	Social Capital Index	FCS (Food Consumption Score)[b]	Months Insecure[c]
Gulu	Most	352 (80)	99 (32)	573 (76)	2.1	1.4	55	3.0
	Least	1,153 (95)	1,205 (79)	4,403 (90)	2.4	1.5	55	1.7
Lira	Most	347 (60)	131 (45)	1,072 (50)	1.9	2.0	47	3.2
	Least	1,072 (83)	474 (56)	5,733 (67)	2.3	2.0	60	2.3
Luweero	Most	243 (49)	138 (30)	1,139 (50)	1.5	2.0	80	4.1
	Least	809 (57)	1,053 (57)	5,004 (86)	1.9	2.0	91	2.7
Mbale	Most	225 (61)	293 (25)	1,433 (45)	1.4	1.8	65	3.9
	Least	635 (82)	832 (63)	7,180 (78)	1.8	2.1	79	3.1
Isingiro	Most	707 (88)	1,800 (44)	1,578 (47)	2.1	1.9	69	3.2
	Least	4,728 (90)	4,624 (64)	9,913 (72)	2.4	2.3	76	2.5
Kasese	Most	745 (80)	200 (42)	1,150 (56)	1.9	2.2	72	4.6
	Least	1,492 (93)	587 (59)	4,014 (74)	2.2	2.3	81	3.5
Total	Most	482 (70)	444 (37)	1,085 (55)	1.8	1.9	64	3.7
	Least	1,965(84)	1,516 (62)	5,767 (77)	2.2	2.1	78	2.9

Key:
[a] = Numbers are in '000 shillings (percentage with income in parentheses).
[b] = Food Consumption Score—an FAO measure of diet diversity.
[c] = Number of months households reported food insecurity in 2011.

Much of Uganda is characterized by distinct "hungry seasons"— periods that coincide with the beginning of the agricultural campaign. During this period, a household usually reduces daily consumption by cutting the amount of food consumed or eliminating one daily meal. Many households also substitute their usual food for less desirable but more accessible foods.

For the most vulnerable households, this period of insufficient access to food may begin earlier and last longer. The results in Table 6 reveal that in all the districts, the most vulnerable household types experienced longer periods of food insecurity in 2011. Furthermore, compared with reported months of food insecurity in 2006-2007, the most vulnerable households in all districts saw their food security situation deteriorate, while all of the least vulnerable households improved on average.

Gender. To further improve understanding of the role gender may play in the vulnerability of households, the female-headed household sample was analyzed, as was the perceived impacts of climate change on women, reflected in the FGD data.

Information from the household survey on female-headed households vs. jointly managed households is presented in Tables 7-9. The information shows that approximately 21 percent of households in the survey were headed by females, with a range of 8.3 percent in Mbale, 16.5 percent in Kasese, close to 23 percent in Lira and Isingero, and closer to 30 percent in both Gulu and Luweero. Surprisingly, the differences between female-headed and jointly managed households are not as marked as one might anticipate. As expected, the percentage of female-headed households in the most vulnerable category was higher than jointly managed households, with the notable exceptions of Luweero and Kasese. In Kasese, and to a lesser extent in Luweero, the size of land holdings is relatively low, although off-farm income sources are relatively high. Female-headed households have less education with the exceptions of Gulu and Mbale, less land with the exception of Mbale, fewer people in their households, and markedly lower incomes. However, as total income grows, the difference between jointly-managed and female-headed households' vulnerability categories decreases, supporting the hypothesis that women with access to more income are less vulnerable. Indeed, in Kasese and Luweero, where the income gap is smaller, there is a smaller difference between the number of female-headed and jointly managed households in the most vulnerable category.

Even though average education and off-farm income scores are higher for female-headed than jointly managed households in Gulu, all female-headed households are in the most vulnerable category and their average total income is the lowest relative to other categories and jointly managed households in Gulu. Such a pattern could suggest that women might be engaging in strategies (e.g., improving the education of household members and engaging in more off-farm income generation activities) to improve their situations. The low levels of income may reflect that members of these households may be engaged in cheaper, unskilled income generation opportunities (e.g., clearing fields and forests, small-scale marketing of farming products, etc.).

TABLE 7. DISTRIBUTION OF HOUSEHOLDS BY GENDER, VULNERABILITY CATEGORY, AND DISTRICT

District	Overall % of Female-Headed	% of Female-Headed by Vulnerability Group		% of Jointly Managed by Vulnerability Group	
Vulnerability		Most	Least	Most	Least
Gulu	27.5	100	0	78.2	21.8
Lira	23.3	89.3	10.7	83.7	16.3
Luweero	30.8	62.7	37.3	70.3	29.7
Mbale	8.3	90	10	76.4	23.6
Isingiro	23.3	78.6	21.4	64.1	35.9
Kasese	16.5	63.6	36.4	63.6	36.4
Total	21.1	80.5	19.5	70.7	29.3

TABLE 8. HUMAN CAPITAL OF HOUSEHOLDS BY GENDER AND DISTRICT

District	Household Size		Dependency Ratio		Education Score	
Gender	Male	Female	Male	Female	Male	Female
Gulu	7.2	6.1	1.3	1.5	.52	.54
Lira	6.5	4.9	1.3	1.1	.55	.33
Luweero	5.9	4.8	1.4	1.8	.93	.68
Mbale	6.9	4.9	1.1	.9	.77	.91
Isingiro	6.7	5.6	1.2	1.4	.72	.69
Kasese	6.5	5.9	.9	1.0	.69	.53
Total	6.6	5.4	1.2	1.3	.70	.58

TABLE 9. LAND, INCOME, OFF-FARM SHARE BY GENDER AND DISTRICT

District	Land		Total Income		Percentage Off-Farm Income	
Gender	Male	Female	Male	Female	Male	Female
Gulu	3.4	2.5	1941	625	44	51
Lira	2.8	2.2	1621	799	38	38
Luweero	2.1	1.7	2548	1896	55	39
Mbale	1.8	2.1	2203	1629	47	22
Isingiro	7.2	5.7	6968	3302	36	21
Kasese	5.7	2.9	2741	2249	40	52
Total	3.4	2.8	2965	1752	43	40

Information from the FGDs, combined with secondary data sources, improve understanding of some of the constraints men and female-headed households face in the districts studied. Rural households in Uganda depend on farming as their main source of income, and 90 percent of women in the rural areas work in the agricultural sector (IFAD, 2000). In addition to agricultural work, rural women are responsible for caring for family members. Consequently, rural women spend nine hours a day on domestic tasks, such as preparing food and clothing; fetching water and firewood; and caring for the elderly, sick, and orphans. Women on average work longer hours than men, between 12 and 18 hours per day, whereas men average between 8 and 10 hours a day (World Bank, 2005).

The FGDs highlighted other constraints such as women's lack of control over land and cash crops, also reflected in the survey data. Respondents reported that in difficult times, when crops fail, women bear the burden of agriculture labor: opening up new fields, if land is available; manually weeding to control pest and diseases; and selling their agricultural labor to generate income.

Conclusions

The characteristics of the HLTs begin to define the parameters of sensitivity to climate stressors. Specific characteristics make some households more sensitive to climate variability and change. For example, members of more vulnerable households are generally less well educated and participate less frequently in community groups such as production associations, cultural or labor savings groups and religious organizations. Further, these households:

- Have a lower proportion of able-bodied members;
- Are more likely to be headed by females;
- Are less likely to sell a portion of their crops and livestock;
- Have less access to loans; and
- Less frequently gain income from off-farm sources (and when they do earn off-farm income, it is less than the amounts that more secure households earn).

Where different stocks of capital are available to household decision makers, the level of sensitivity is reduced, and households are better prepared to cope with the immediate impact of climate change. Members of less vulnerable households are better able to absorb climate change related shocks because, on average, they have:

- A higher ratio of producers to non-producers in the household;
- More educated household members and children who are in school;
- Larger land holdings;
- More livestock—particularly cattle, which they sell when they need resources;
- The tendency to engage in off-farm income generation; and
- Participated in community activities (producers associations and savings and loan groups).

2.2.3 WATER USE FOR AGRICULTURE

Uganda is increasingly focusing on the impact of climate change on the country's water resource base. The management of the water resource base becomes a valid concern as temperatures continue to rise, and precipitation becomes more variable with an increased possibility that extreme weather events will become more frequent. Resulting changes from the impact of these climate stressors will have a direct impact on Ugandan agriculture.

Increased temperatures will likely result in higher rates of evaporation and lower levels of soil moisture for agriculture. Limited surface water infrastructure inhibits flood and drought response options, while uncontrolled and inadequate land use and wetland degradation will continue to increase future damage from flooding and extreme weather events. Despite these facts, Uganda is well endowed with water resources. The abundance of surface water has not forced the country to focus on establishing integrated water resource management systems until fairly recently. It appears as though the country will be able to significantly expand its surface water irrigation at the macro level without threatening the resource base.

Nevertheless, these climate-related drivers combined with non-climate stressors are projected to increase water stress in localized pockets. Non-climate stressors include population growth, urbanization, increased agricultural irrigation extraction, poor land use methods, increased pollution and wetland intrusion. Extreme increases in water extraction rates for large-scale surface water irrigation could have impacts in localized areas and for lower basin countries.

Data availability for groundwater is more limited than data available on surface water. Large-scale commercial farming based on groundwater irrigation seems not to be currently viable; constrained by a number of factors—institutional, financial, social and environmental. Sustainable extraction for irrigation will require detailed and comprehensive hydrogeological studies, regulation, and monitoring.

Uganda will likely remain focused on rain-fed agriculture for the short to medium term, largely because it will take time to finance and build irrigation infrastructure. Those that can afford it will likely transition toward supplemental irrigation, but many of the most vulnerable small-scale stakeholder farmers will not be able to irrigate their agricultural lands due to financial and access constraints. Transition to groundwater-irrigated agriculture for areas far from surface water sources, seems unlikely due to high infrastructure investment costs and slow cost recovery. Recent trends suggest that most small-scale farmers will prefer to rely on low-cost surface water irrigation methods. However, uncontrolled expansion will increase the problem of wetland intrusion (farmers converting natural wetlands into cultivation—primarily rice) as noted in the FGDs and key informant interviews, particularly in Gulu.

Wetland degradation and intrusion will amplify the future risk of flooding and crop production in reclaimed wetland areas. Historically, water has not been economically valued in Uganda and there is no incentive for conservation or protection of environmental flows in wetlands and upper watershed areas. These factors combined with weak institutional structures will likely result in poor protection for key ecological services. The key informant interviews (KIIs) conducted at the district level found that although wetlands and many forests are legally protected, resources and staff to enforce protection are severely limited.

From an institutional perspective, water allocation systems are weak and largely undeveloped. It is encouraging that the GoU is moving toward the implementation of Integrated Water Resource Management principles in its catchment-based water management structure.[30] However, institutional capacity and resources to apply the principles remain a challenge.

2.3 ADAPTIVE CAPACITY

As described above, the adaptive capacity of a household (or a livelihood system) enables it to recover from a shock or stress and to return to a pre-shock level of security. Accordingly, the household with high adaptive capacity is less vulnerable. In the current climate change literature, adaptive capacity is often equated with household or community resilience (e.g., the assets and institutions that allow households to absorb shock and to build local defenses against subsequent stressors). In this study, the measure of adaptive capacity is based upon the profiles of the different household livelihood types. With this analysis of livelihood strategies, three broad adaptive pathways were defined.

The first adaptive pathway is the **adoption of new technology**. Technologies either exist or can be developed to mitigate or eliminate climate-induced stressors, as is the case with irrigation and crop-resistant varieties. From the FGDs, the kinds of technologies that were adopted in the past in response to non-climate and climate stressors include: new plant varieties, an increase in pesticide use, changes in crop mixes and planting seasons, use of diverse soils and locations (wetlands and uplands), water management through contour planting and terraces, drainage canals, soil management through mulch, mounds and manure, post-harvest treatments with pesticides, cereal banks to replace lost seed, and the use of tarpaulins for drying. Farmers reported that many technological innovations introduced on-farm resulted from information sharing with fellow farmers or through informal experimentation. Other innovations, however, came about as a result of national research programs, effective extension services, functioning input markets, road infrastructure and even social organizational shifts (e.g., irrigation committees or farmers' associations).

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[30] USAID defines IWRM as: *"IWRM is a participatory planning and implementation **process**, based on sound **science**, which brings together **stakeholders** to determine how to meet society's long-term needs for water and coastal resources while maintaining essential **ecological** services and **economic** benefits."*

A second adaptive pathway is **on-farm investment**. Following this pathway, investment allows farmers to purchase more land, plant trees, mechanize, install irrigation and water conservation structures, and construct post-harvest facilities, all of which effectively increase adaptive capacity. The capital for investment strategies usually comes from the conversion of existing household assets or from outside sources such as formal and informal lending services. Again, from the focus group interviews, farmers cited the use of village savings and loan associations and other sources of microfinance lending when making investments such as acquiring oxen or tractors to mechanize, and investing in direct marketing of their products.

The third adaptive pathway is **diversification of household revenue streams**. During the FGDs, farmers pointed to diversification strategies that reallocate household labor into income-generation activities that create income streams protected from or, neutral to, climate variation. These include brick-making, brewing, shop keeping and so on. Farmers also cited the diversification of farm investments such as adding livestock or planting trees.

It is clear that these sources of adaptive capacity are interrelated. Households that retain more wealth stored in land, livestock and other assets, and which have access to outside sources of investment and manage to maintain diverse income portfolios, are less vulnerable to climate stress. While levels of adaptive capacity vary across households, a general pattern emerges—notably, that the households with greater adaptive capacity have access to, and can effectively manage, larger flows of information and possess more investment capacity either from household stocks or from external sources.

This section, quantifies the relative level of adaptive capacity associated with the different HLTs. To do so, a relative index of adaptive capacity was created on a score from 1 to 12, with the lower numbers signifying smaller levels of adaptive capacity (see Tables 10-12 and Figure 10).

2.3.1 ASSETS

In Table 10, a composite ranking is based on a set of asset variables that include land (cropland), household wealth (asset index), livestock and the total social capital index (based on level of participation and exchange). Consistent with the livelihood framework, these sets of variables represent the resources available to households to either reconstitute an asset base or to invest. They also offer a rough accounting of the stock of economic and social wealth reported within households. Within these asset rankings, the differences between the two vulnerability groups are stark. This is true for all the component variables, including social capital. Overall, by HLT, both the Isingiro groups scored highest, regardless of the respective vulnerability status owing to their larger stock of cropland and asset wealth (which includes trees and productive assets). The most vulnerable groups in the four districts of the north, central and east (Gulu, Lira, Luweero, and Mbale) scored lowest in these asset rankings. The land scarcity for both most vulnerable and least vulnerable groups in Luweero and Mbale is also reflected in this ranking.

TABLE 10. ASSET RANKINGS AS A COMPONENT OF ADAPTIVE CAPACITY

Vulnerability Level		Household Asset Rankings				
		Cropland	Owned Assets	Livestock Sold	Social Capital	Total Ranking
Most Vulnerable Households	Gulu	6	1	1	3	3
	Lira	4	3	3	4	4
	Luweero	2	2	2	2	1
	Mbale	1	4	4	1	2
	Isingiro	11	10	10	8	10
	Kasese	7	6	5	9	7
	TOTAL	31	26	25	27	27
Least Vulnerable Households	Gulu	8	5	11	7	8
	Lira	9	9	6	10	9
	Luweero	3	7	9	6	5
	Mbale	5	9	8	5	6
	Isingiro	12	12	12	12	12
	Kasese	10	11	7	11	11
	TOTAL	47	52	25	51	51

Key:
Cropland: 1 = least cropland – 12 = most cropland
Owned Assets: 1 = lowest level of assets – 12 = highest level of assets
Livestock: 1 = least livestock sold – 12 = most livestock sold
Social Capital: 1 = lowest level of social capital – 12 = highest level of social capital
Total: 1 = lowest level of household assets – 12 = highest level of household assets.

2.3.2 DIVERSIFICATION

Table 11 summarizes the rankings of HLTs based on variables relating to diversification. As defined here, diversification is the outcome of household decision-making that aims to reduce risk (Ellis and Bahiigwa, 2003). Diversification strategies encompass both on-farm decisions as well as off-farm resource allocations. The variables used to measure this component of adaptive capacity include the number of different crops sold and of different income sources; the number of migrant family members (as a source of remittance income); the percentage of off-farm income (relative to total income); and the household educational score. The use of the latter to measure diversification is justified by the fact that climate-neutral income generation is usually enhanced by education levels. Using these indicators of diversification, the rankings again show that diversification makes a decidedly greater contribution to adaptive capacity among least vulnerable HLTs. Agricultural diversification is strongest in Isingiro and Kasese, where both the most vulnerable and least vulnerable households occupy the top four ranks.

On-farm diversification is partially dependent upon access to land—especially access to different land types (forest, pasture, wetlands, etc.). Thus in Kasese and Isingiro, the diversity of crops is higher for both vulnerability categories. In contrast, in Luweero and Mbale, where land is relatively scarce, agricultural diversification is very limited, as are the number of different income sources.

The least vulnerable Lira, Luweero, and Mbale HLTs show strong position rankings in the contribution of off-farm income and household educational scores. In the case of Lira, it is evenly balanced among agricultural and income diversification. Luweero and Mbale feed off the economic (and employment) opportunities of the capital city and airport, thus providing incentives for more education and skill-building activities. The lowest rankings for overall diversification are found in the most vulnerable HLTs of Lira, Luweero and Kasese, where the share of off-farm income and educational scores are relatively lower.

TABLE 11. DIVERSIFICATION RANKINGS AS A COMPONENT OF ADAPTIVE CAPACITY

Vulnerability Level		Diversification Rankings					
		Crops Sold	Income Sources	No. of Migrants	Percentage Off-Farm	Education Score	Total Ranking
Most Vulnerable Households	Gulu	6	10	5	6	1	6
	Lira	4	3	2	2	2	1
	Luweero	1	2	6	4	8	2
	Mbale	2	1	9	5	7	4
	Isingiro	11	4	8	1	4	6
	Kasese	9	5	2	2	4	3
	TOTAL	33	25	33	21	24	31
Least Vulnerable Households	Gulu	7	12	4	9	5	8
	Lira	8	6	11	10	10	11
	Luweero	3	7	10	12	12	10
	Mbale	5	11	7	11	10	10
	Isingiro	12	8	12	7	11	12
	Kasese	10	9	1	8	6	7
	TOTAL	45	53	45	57	52	58

Key:
Crops Sold: 1 = least crops sold – 12 = most crops sold
Income Sources: 1 = least income sources – 12 = most income sources
No. of Migrants: 1 = least number of migrants – 12 = most number of migrants
% Off-Farm: 1 = lowest % of off-farm income – 12 = highest % of off-farm income
Education Score: 1 = lowest education score – 12 = highest education score
Total: 1 = lowest level of diversification – 12 = highest level of diversification

2.3.3 ACCESS TO EXTERNAL RESOURCES FOR INVESTMENT

In Table 12, an index of access to outside investment (for the acquisition of new technology) is presented along with the overall rankings for adaptive capacity. The proxy variable used to estimate investment was the shilling value of loans by the different HLTs over the last year. The least vulnerable households in all districts occupy the highest rankings for this indicator, with Luweero in first place followed by Kasese (coffee production), Isingiro (matooke production), and Mbale (coffee production). Luweero's ranking most likely reflects the greater economic activity throughout that district.

Combining the assets, diversification and investment components, the overall ranking in adaptive capacity shows the least vulnerable household types in Isingiro, Lira and Kasese in the top three positions, followed by the most vulnerable households in Isingiro. The lowest adaptive capacity is located among the most vulnerable households of Gulu, Lira, Mbale, and Luweero. These are the households that have fewer assets, less balanced income strategies and less capital for investment.

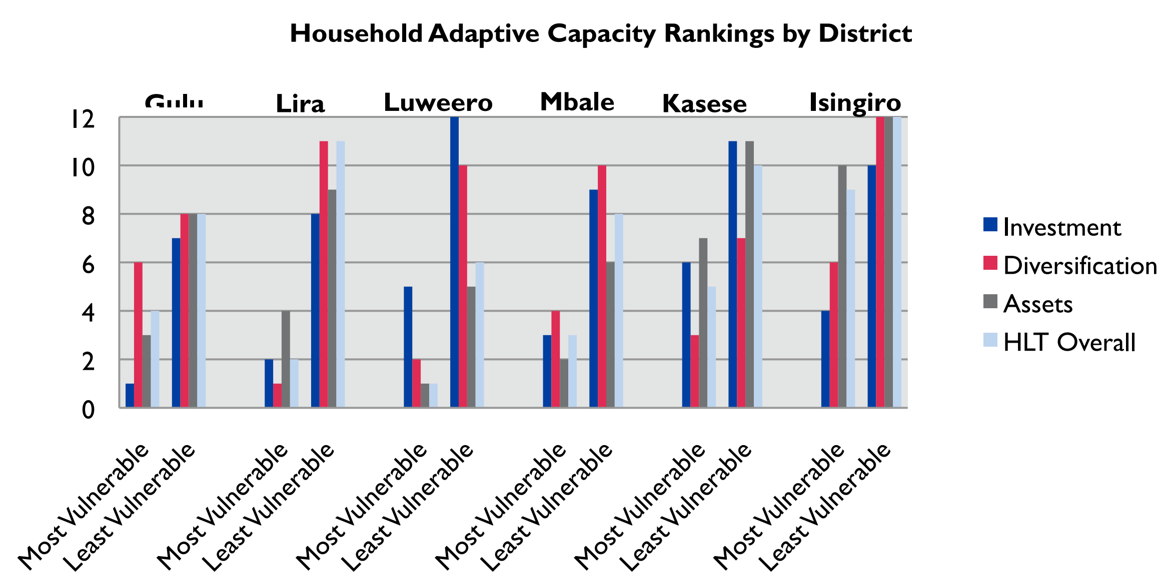
TABLE 12. INDEX OF INVESTMENT AND OVERALL ADAPTIVE CAPACITY RANKINGS

Vulnerability Level		Investment Rankings	HLT Overall Rankings
		Loan Values	
Most Vulnerable Households	Gulu	1	4
	Lira	2	2
	Luweero	5	1
	Mbale	3	3
	Isingiro	4	9
	Kasese	6	5
	TOTAL	21	24
Least Vulnerable Households	Gulu	7	8
	Lira	8	11
	Luweero	12	6
	Mbale	9	8
	Isingiro	10	12
	Kasese	11	10
	TOTAL	57	55

Key:
Investment: 1= lowest level of loan value in shillings – 12 = highest level of loan value in shilling.
Overall Rankings: 1= lowest level of adaptive capacity – 12 = highest level of adaptive capacity

Figure 10 aggregates the adaptive capacity information presented in Tables 10 to 12 comparing household assets, diversification, investment, and overall adaptive capacity rankings by district and vulnerability group. The chart shows important variations among adaptive capacity categories, districts and HLTs described above and highlights these differences across the three rankings by district.

FIGURE 10. SUMMARY OF HOUSEHOLD ADAPTIVE CAPACITY RANKINGS BY DISTRICT



2.4 INSIGHTS FROM THE INTEGRATIVE ANALYSIS: VULNERABILITY OF UGANDAN AGRICULTURE

This assessment emphasizes that climate vulnerability varies widely across the country and its impacts are primarily experienced locally. Thus, local responses and solutions will also be required as part of the national plan for climate adaptation. This climate analysis, along with farmer perceptions derived from FGDs, demonstrates that temperatures are projected to increase significantly, while rainfall—although not expected to increase—will become more variable with likely increases in extreme events. Depending on the district, increasing temperatures may affect the phenological cycles of coffee, increase pest populations and disease in root crops and matooke and result in more frequent dry spells and severe storms that compromise maize and bean productivity.

Farmers consistently assert that the nature of the rainy season(s) is changing, insects and crop disease have increased and severe weather events are more common. Given these characteristics of exposure, where does vulnerability to climate change lie? Overall, the lowest percentages of most vulnerable households are found in Isingiro, Kasese, and Luweero, and the highest in Gulu and Lira. In the rankings of HLTs, however, even the most vulnerable households in Isingiro have a higher adaptive capacity than the least vulnerable households in the other districts.

As a general pattern, Isingiro and Kasese are characterized by stronger agricultural bases with more land and significant access to off-farm revenue. More cropland, more forested area and pasture means a more diversified crop mix, greater integration into market activities (despite the remoteness of some sub-counties) and a higher degree of agricultural professionalization. These two districts are indeed sensitive to climate change and variability (matooke in Isingiro and coffee in Kasese), but the least vulnerable farmers are more diversified and have more household resources to invest in technological change and adaptation strategies. For populations living in Luweero, and to a lesser extent in Mbale, the proximity to Kampala or Kenya seems to have resulted in greater access to educational opportunities and more off-farm employment. Nevertheless, the most vulnerable farmers in these two districts have a high level of sensitivity to climate change (coffee, maize, and root crops) because of underlying land scarcity and limited diversification potential. The most vulnerable groups in Lira and Gulu are defined by lack of resources generally and of diversification options. In addition, these households rank the lowest in terms of education.

The principal vulnerability message is that the most vulnerable households—concentrated in Lira, Gulu, Mbale and Luweero—are victims not only of climate variability, but of the structural poverty that characterizes so much of the agricultural sector. These households are highly vulnerable because many live on a cash-scarce threshold of basic subsistence where any reduction in production or income results in a crisis for the household economy. There are few reserves, few assets or savings and few alternatives to fall back on in times of stress—climate or otherwise. Where sensitivity is highest, for example, among the most vulnerable farmers of Mbale with such limited land and a dependence on coffee, only a minor change in climate would compromise the viability of the livelihood system.

Any adaptation process should integrate across sectors: environment, agriculture, water, governance and education; and across administrative levels: national, district and local. The investment plan must address local vulnerability. Research, extension, credit, social services, and private sector participation must all play a role in adaptation. Finally, the reality is that there are many people trapped in agriculture, dependent on a highly uncertain and sensitive (to climate) livelihood because they have no other options. Over the long run, a climate strategy should also be a development strategy, and access to non-agricultural livelihoods—with the necessary education and skills' building to enable it—will ultimately reduce the vulnerability of those who choose to leave agriculture and those who opt to remain. The recommendations in the next section present viable options for achieving this strategy.

3.0 RECOMMENDATIONS AND ADAPTATION OPTIONS

In developing recommendations from the vulnerability assessment, different approaches emerge: investing in local versus national-scale adaptive strategies, and short-term versus long-term strategies. The assessment substantiates the fact that climate change is locally experienced. Adaptive strategies developed at national scales might not be locally appropriate, particularly when their adoption is complicated by the influence of local ecosystems and social and cultural relations. National programs that are not complemented by locally relevant and tested adaptive strategies are unlikely to produce useful strategies for most farming communities. On the other hand, this assessment reiterates that while adaptation occurs farm by farm, the identification and dissemination of adaptation options—and the enabling of their adoption—requires a national effort. Similarly, with regard to time horizons, although some adaptations and adaptation policies are short term and require more immediate action, other policies and practices will yield adaptive benefits over the long run.

These geographic and time-scale considerations led the assessment team to define four overarching strategies as a framework for an approach to develop and implement the recommendations:

1. **Decentralize experimentation and innovation**, building the capacity of farmers and their organizations to generate, test, and adapt new ideas and to implement those that are locally viable in a changing climate. Professional researchers and extension agents act as supportive partners in this effort, multiplying the options from which farmers can choose.
2. **Take an agro-ecosystem approach**, so that climate change impacts on soils, water, forests, wetlands, and other ecosystem elements inform decisions about agricultural value chains and livelihoods at the district level and below.
3. **Better integrate climate change information into national strategic planning**, so that system-wide changes in crop mixes or sector investments can be anticipated and planned for.
4. **Intensify the pace and deepen the reach of learning among actors in climate change adaptation**, across vertical and horizontal networks, and through social learning platforms. This effort will require facilitation, training, and incentives for collaboration among researchers and farmers. The outcome should be a faster system response to changing conditions.

This strategic approach aims to improve cohesion in USAID's support for adaptation, and to help the agency and others set priorities for action.

Within this framework, we propose the more specific recommendations below. We divide the recommendations by activity focus: establishing the national context for adaptive agriculture, research and learning across stakeholder groups, and strengthening and diversifying livelihoods. Where appropriate, we identify district-specific recommendations that are consistent with their agro-ecosystems, livelihood options, and socio-cultural practices. The recommendations presented herein are enriched by options generated by key stakeholders from government, donor agencies, research organizations, and civil society during a participatory multi-stakeholder options analysis meeting, which took place in Uganda on January 31, 2013 (see Annex F, The Uganda Options Analysis Workshop Report).

3.1 NATIONAL CONTEXT FOR ADAPTIVE AGRICULTURE

This section refers to establishing policies and investment strategies that address large-scale, long-term threats to value chains, livelihoods, and agricultural institutions. It also includes recommendations that facilitate local adaptation over shorter time periods, with an emphasis on improving the content and pathways for communicating information between researchers, scientists, and farmers:

1. Build the capacity of the Uganda Department of Meteorology (DOM); Climate Change Unit (CCU); and the Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF) **to improve the production, distribution, and use of climate information that responds to the needs of decision-makers, as well as farmers and other stakeholders.**

   Provide necessary technical and financial support to DOM and CCU for the development of the national climate datasets and information. Enhanced monitoring capabilities are needed in Uganda because of the diversity of climatic and environmental conditions: topographical and hydrological, as well as the seasonality and high inter-annual variability of rainfall. Potential lead actors include UMD and CCU. Supporting actors include the agricultural research service (NARO), the rural extension service (NAADS), universities, MAAIF, donors, and NGOs.

   - Maintain, modernize, and expand the meteorological observation network.
   - Update and maintain well-documented, operational, and real-time national datasets of daily rainfall values and temperature (both T-min and T-max).
   - Develop a mechanism to share datasets with universities, research centers, the Government of Uganda, ministries, and other partners.
   - Build rainfall and temperature datasets with higher spatial coverage that merges in situ data with high-resolution satellite data. The merged datasets will provide information on current as well as historical climate in locations that have no records.
   - Maintain and use the above datasets to support national strategic planning as well as decentralized innovation and adaptation.
   - Support research institutions in developing—and DOM and/or CCU in implementing—climate impact monitoring tools tailored to users' needs. Monitoring and forecasting products ideally will foster engagement between information producers and stakeholders to better evaluate their capacities, needs, and information dissemination channels. These efforts will also build stakeholder capacity to understand climate variability and change and the need for flexibility and adaptation.

   Build capacity of Ugandan institutions to develop and routinely use downscaled climate projections. Potential lead actors include DOM, CCU, universities, the Consultative Group on International Agricultural Research (CGIAR). Supporting actors include MAAIF, donors, and nongovernmental organizations (NGOs).

   - Implement tools for statistical downscaling. Build capacity to use those tools and interpret results among a wide range of actors with an explicit discussion of uncertainty.
   - Evaluate optimal ways to disseminate climate change information at district levels, including formats best understood and accessible to individual farmers. The aim is to improve both

strategic planning (by making information more district-specific) and to assist farmers in their own adaptive planning.

- Develop the capacity of research, operational, and government institutions to evaluate potential climate change impacts on agriculture.
- Support the development and implementation of impact evaluation tools such as crop models adapted to and validated within the Ugandan context.

Develop a platform/mechanism for results (current trends and projections) to be shared at regional, national, district, and local levels within Uganda. Potential lead actors include CCU, MAAIF, NARO, NAADS, CBOs, and NGOs. Supporting actors include donors, NGOs, natural resource management (NRM) agencies, universities, the private sector, and district and local government agencies.

- Create training opportunities and incentives for NARO, NAADS, NRM professionals, water managers, agro-processors, and farmers to form multi-stakeholder learning platforms focused on climate change and adaptation.
- Support NGOs and other organizations to facilitate communication and planning within the platforms.
- Based on information emerging from multi-stakeholder learning platforms, facilitate a process in which districts develop plans for climate change adaptation in agriculture that support farmer/researcher collaborations in developing and testing options.

2. Assist the Government of Uganda to **organize and develop a high-level, multi-sectoral body to support the CCU to strengthen the climate change agenda and guide policy** development.

   Create a multi-sectoral coordinating committee, led by the CCU, to regularly meet to plan cross-sector coordination and strategic investment regarding long-term climate change impacts. Potential lead actors include the Government of Uganda, CCU, and MAAIF. Supporting actors include donors, NGOs, universities, private sector actors, and NRM agencies.

   - Examples of key topics for discussion and decision making during the coordinating committee meetings follow:

     – What are the preferred cropping mix scenarios for different parts of the country given climate change projections (and their level of uncertainty) and farming preferences, and what policies and investments are needed to realize them? This question emerges from improved but uncertain climate information and potential climate change impacts on specific crops. Farmers' interest in and capacity to change varieties, inputs, or management strategies to prolong the viability of valued crops under changing climatic conditions also need to be considered.
     – What should be the role of agriculture in the economy and culture in the long term, given climate change projections, and what policies and investments are needed to get to the ideal? This question also emerges from the climate change information and potential climate change impacts on crops and, more broadly, agro-ecosystems. Discussions should consider the different non-farm livelihoods that might be available in some districts, such as Mbale, which could relieve pressure on agriculture.

Mainstream a climate change perspective into the programming of agricultural and natural resource management services. Consider mainstreaming into other sector services affected by climate change such as health, disaster risk reduction, and education. It will not be enough for the coordinating committee to define responses to climate change; government officials and their NGO and research partners at lower levels will need to engage citizens in the process of change and provide support to implement the changes. Potential lead actors include the Government of Uganda, MAAIF, NRM agencies, and CCU. Supporting actors include NAADS, NARO, NGOs, donors, CBOs, NGOs, and private sector actors.

- Develop and implement training opportunities and incentives for professionals at the district level and below to take on climate change adaptation as a part of their work.
- Ideally, the content of training would emerge from multi-stakeholder platforms that include CBOs, NGOs, and the private sector.

3.2 RESEARCH AND OUTREACH AT THE NATIONAL, DISTRICT, AND COMMUNITY LEVELS

This section refers to how knowledge and information related to climate change adaptation is generated and shared. Consistent with the framework, specific recommendations encourage the decentralization and democratization of innovation and planning, while also improving the exchange of information among all actors concerned with adaptation, and quickening the pace at which they learn from each other:

1. **Develop a wide range of high-yielding and climate appropriate crop varieties, farm management strategies (focused on diversification and intensification of farming), and post-harvest storage strategies from which farmers can choose.** Ideally, multi-stakeholder dialogues and platforms, similar to the one recommended above, shape the evolution of the choices generated with and for farmers. Given the long lead time for developing some choices, however, the assessment team recommends that work start immediately on the activities listed below, as farmers have already identified them as priorities. Potential lead actors include MAAIF, NAADS, NARO, CGIAR, and universities. Supporting actors include CBOs, NGOs, and private sector actors. Adaptive choices should meet the locally specific challenges of the following:

   A gradual increase in temperature—the top priority—given the level of certainty of the outcome and its likely impact on key crops:

   - Maize and beans: Investment in heat-resistant varieties of maize and beans that meet local preferences is a key need, as are improvements in soil moisture management.
   - Coffee and matooke: Investments in shading and other temperature-reducing management techniques are a top priority for coffee and matooke. So too is soil moisture management in order to offset expected increases in evapotranspiration.

   Variable rainfall that affects the moisture of soil, the phenological stages of production and post-harvest conditions, and especially increases in "dry season" rainfall, is also a priority given the sensitivity of key crops:

   - Maize and beans, with an emphasis on pest-/disease-resistant varieties that thrive in moist environments, treated seeds, and improved soil moisture management techniques.

The increase of disease and pests associated with increasing temperatures and variable rainfall affects the phenological stages of production and post-harvest conditions. The priority strategies are to maintain at district research centers reserves of seeds and plants that are disease- and pest-free to improve recovery after disease outbreaks, and to develop management strategies that reduce pest and disease risk (priority diseases and pests are listed by crop in Annex C):

- Sweet potato (of the districts studied this would apply to Luweero, Isingiro, and districts with similar agro-ecology);
- Sorghum (of the districts studied this would apply to Gulu, Lira, and districts with similar agro-ecology);
- Cassava (of the districts studied this would apply to Lira, Gulu, Mbale, Kasese, and districts with similar agro-ecology); and
- Rice (of the districts studied this would apply to Gulu, Lira, and districts with similar agro-ecology).

Improved management of agro-ecosystem services, especially the provision of clean water, fertile soil, and micro-climates/habitats is a priority to be defined in each district based on local conditions, and should be integrated with research on farm-management innovations:

- For wetlands (of the districts studied this would apply to Gulu and districts with similar agro-ecology);
- For forests (montane) (of the districts studied this would apply to Mbale and Kasese, and districts with similar agro-ecology);
- For shade (of the districts studied this would apply to Kasese, Mbale, Luweero, and districts with similar agro-ecology); and
- For soil moisture and fertility in all regions.

2. **Strengthen the capacity of farmer groups to experiment with new ideas and to adapt them to local environmental and social conditions.** Care should be taken to promote active participation and leadership by women and men, old and young, and poor and better-off to assure the best mix of adaptive innovations. Pilot programs for farmer experimentation and innovation can be undertaken where local social capital is strong but overall vulnerability is high (of the districts studied Gulu, Luweero, and Mbale would be good candidates for pilot programs). These programs can provide lessons for setting up innovation systems elsewhere. Potential lead actors include CBOS, NGOs, NGOs, NAADS, NARO, CGIAR, and universities. Supporting actors include donors, the Government of Uganda, and private sector actors.

   - Train farmers on experimentation and monitoring and evaluation (M&E).
   - Improve access to inputs in the form of new varieties and management techniques.
   - Provide technical support when farmers encounter problems, and material support (whether through micro-grants, loans, or insurance programs) to reduce risks and labor burdens.

3. **Strengthen the capacity of farmer organizations to link laterally (amongst themselves) and vertically (with other research institutions at district and national levels)**, to scale up the dissemination of successful innovations and adaptations. Potential lead actors include CBOs, NGOs, NGOs, NAADS, NARO, CGIAR, and universities. Supporting actors include donors, MAAIF, the Government of Uganda, and private sector actors.

- Set up and pilot multi-stakeholder learning platforms perhaps at the district level, where vulnerability is high, local social capital is strong, and links to local researchers and among sectors are better established. Of the districts studied Gulu might be suitable for a pilot.
- Lessons from these platforms can inform the creation of platforms across the country.

3.3 LIVELIHOOD STRENGTHENING AND DIVERSIFICATION

This section addresses both the strategic planning and multi-stakeholder learning elements of the framework. Farmers and their families actively engage in strengthening and diversifying livelihoods as they strive to adapt to changing conditions (i.e., conflict, changes in markets, etc.) and improve their well-being, often with the assistance of government and NGOs. Support to improve livelihoods will continue and become even more important under changing climate conditions. For this reason, these recommendations build on existing livelihoods strengthening programs and improve the capacity of farmers to generate ideas about strengthening agricultural livelihoods beyond the safeguarding of production from adverse impacts of climate change. This assessment also suggests that creating and sustaining non-agricultural livelihoods will likely attract investment from the Government of Uganda, NGOs, CBOs, the private sector, and donors:

1. **Provide opportunities to spread financial risk in agriculture to allow for greater innovation and adaptation.** This includes both financial instruments (such as strengthening loan and insurance programs), and also strengthening farmer organizations and their links to consumers, which can additionally spread risk. Potential lead actors include CBOs, NGOs, the Government of Uganda, MAAIF, economic development agencies, and private sector actors. Supporting actors include NGOs and donors.

2. **Strengthen assets to encourage innovation, diversify livelihoods, and improve adaptive capacity**. Assets are a key variable that distinguishes most vulnerable from least vulnerable households. Investing in asset growth for the most vulnerable will greatly reduce their vulnerability. Some of the most important assets noted in this vulnerability assessment are:

   - *Financial assets.* Expanding savings and loan programs, micro-grants for tree planting, or livestock purchasing programs is likely to have the greatest impact in the short term, particularly in places with many asset-poor households. Potential lead actors include the Government of Uganda, economic development agencies, MAAIF, CBOs, and NGOs. Supporting actors include donors and universities.
   - *Human capital.* Expanding training and technical backstopping to encourage local investments in agricultural processing and marketing, particularly in areas where human capital is weak, and where off-farm opportunities are weak. Key actors include the Government of Uganda, MAAIF, education and economic development agencies, CBOs, and NGOs. Supporting actors include donors, NGOs, and universities.
   - *Social capital.* Promoting and strengthening community-based organizations – farmers' associations, self-help and watershed management groups, and contract farming with preferred consumers – are priorities in areas where social capital may be significant, but where links to climate change-related issues are weak. Potential lead actors include the Government of Uganda, MAAIF, NRM agencies, CBOs, and NGOs. Supporting actors include donors, NGOs, and universities.

3. For the Government of Uganda Ministries of Finance, Planning and Economic Development, Trade and Industry, Local Government, and Education; NGOs; CBOs; and the private sector, invest in less

climate-dependent livelihoods. Such investments should target locations where agriculture-based livelihoods are under the most pressure from climate change and other environmental and social developments. Target areas should also consider, however, whether or not non-agricultural livelihoods are promising. There is little sense in encouraging movement out of agriculture if other livelihoods are less viable. Specific recommendations follow:

- Promote agricultural processing. This option can strengthen farmers' markets even while reducing pressure on agricultural resources. Attention should be paid, however, to whether processing changes farming practices in ways that cause environmental or social harms. Potential lead actors include the Government of Uganda, MAAIF, economic development agencies, CBOs, NGOs, and private sector actors. Supporting actors include donors, NGOs, and universities.
- Develop apprenticeship programs for youth. Particularly in areas where the potential for commercial activity is higher, investing in training programs for youth to take up non-agricultural activities diversifies livelihoods and reduces vulnerability. Potential lead actors include government agencies focused on youth and education, agencies focused on economic development, and NGOs. Supporting actors include donors, NGOs, and private sector actors.
- Support functional numeracy and literacy training along with basic business skills training where there are opportunities for commercial activities. These activities may also be supported across the country, as they will improve farmer capacity to innovate in agriculture.
- Programs that improve school assistance and retention rates, particularly for girls. As such investments are likely to improve local capacity for effective agricultural innovation, as well as support non-agricultural activities; they should be pursued in all districts. Potential lead actors include government agencies focused on youth and education, agencies focused on women and girls, CBOs, and NGOs. Supporting actors include donors, NGOs, and private sector actors.

3.4 PRIORITIZATION OF ACTIONS

The following sections prioritize actions according to three categories: 1) high priority; 2) second-tier; and 3) third-tier. The actions are prioritized based on the exposure, sensitivity, and adaptive capacity of vulnerable populations. The vulnerability assessment has integrated the analysis to identify where investments are both most needed and likely to bear fruit. At the same time, the authors recognize the importance of sequencing. For example, it is necessary to build capacity to experiment with new crop management systems or the establishment of learning platforms before proposing specific technical interventions.

HIGH PRIORITIES are those that require immediate action. They should have first access to funding opportunities and feature prominently in the job responsibilities of those charged with climate change adaptation within agriculture.

1. Initiate pilot programs for farmer experimentation and innovation where local social capital is strong, but overall vulnerability is high(such as in Gulu, Luweero, and Mbale).
2. Initiate pilot multi-stakeholder learning platforms where vulnerability is high, local social capital is strong, and where links between sectors and to local researchers are better established. Of the six districts studies, Gulu might be suitable for the first pilot.
3. Support development and testing of climate products and dissemination strategies that respond to farmers' needs by taking advantage of existing climate information and building two-way communication channels between districts/farmers and central government/DOMs:

a) Develop and disseminate tailored climate monitoring products – short-term and seasonal forecasting – at the farmer level; build capacity from the district level down to the farmer level to use the aforementioned products.
b) Build capacity from the district level down to the farmer level to understand the concepts of climate change and climate variability and the uncertainty attached to climate change projections.

4. Create and maintain an operational database with historical records from all available sources that record meteorological variables, ensure timely updates of records, and design and operationalize climate products that respond to stakeholder needs.
5. Create a cross-sector coordination and strategic investment platform – i.e., a multi-stakeholder coordinating committee led by the CCU.
6. Develop options for farmers to adapt high priority crops:
   a) Develop varieties and management strategies to help farmers adapt coffee, matooke, maize, and beans to increased temperatures, with a target increase of 4 °C. matooke/coffee intercropping is a promising example of a management strategy.
   b) Develop varieties, soil moisture, and post-harvest management strategies that adapt maize and bean production to higher "dry season" moisture.
   c) Create clean stock of seed/plant stocks for matooke, sorghum, sweet potato, and cassava to address disease concerns associated with higher temperatures and variable moisture; improve distribution channels to ensure that the improved stock is accessible to farmers.
   d) Integrate consideration of ecosystem services into the development of choices, particularly for soil moisture and shade impacts.
7. Invest in basic numeracy and literacy in order to support local innovation, communication, and collaboration with other actors. Such an investment will improve the ability of the most vulnerable groups (i.e., women, landless, orphans, etc.) to engage in social and economic activities, extension services, etc. This work will ultimately improve equitable access to opportunities.

SECOND-TIER PRIORITIES require action in the short term (two to four years). These activities should be built into budget proposals immediately and integrated into programs in the short term. Many represent the follow up to, or expansion of, high priority actions.

1. Create innovation and experimentation systems across Uganda based on lessons from pilot projects.
2. Create learning platforms across Uganda based on lessons from pilot projects.
3. Build capacity of a wide range of research institutions, decision makers, and stakeholders to derive and understand localized projections (including limitations and uncertainty); and to project potential impacts on agricultural and ecosystem resources.
4. Facilitate district plans for climate change adaptation in agriculture that are ideally linked to learning platforms and supported by the multi-stakeholder coordination committee.
5. Design training and incentives for officials at the district level and below to include climate change adaptation in plans.
6. With farmers, develop varieties and management strategies (cropping mixes, sustainable pesticide treatments, and post-harvest management) that adapt sorghum, rice, sweet potato, and cassava.
7. Integrate consideration of ecosystem services into development of choices for farmers.
8. Strengthen loan and insurance schemes to reduce risk for innovation in agricultural practice.
9. Develop pilot programs to increase financial and human capital assets in view of low levels of human capital and limited off-farm employment and commercial potential.
10. Invest in numeracy and literacy across Uganda to support expansion of farmer-led experimentation and collaboration in multi-stakeholder platforms.

11. Develop pilot programs to extend social capital to improve adaptive capacity, including water management, risk reduction through contract marketing, and value-added processing.
12. Build links between matooke and coffee processing and marketing to allow farmers to move up the value chain for both crops together.
13. Invest in agricultural processing of high-value crops. The promotion of shade-grown specialty coffees and matooke processing is supported by the Government of Uganda as a way of targeting high-value export markets.

THIRD-TIER PRIORTIES require action in the midterm (three to five years). These recommendations should be built into planning now, with links to lessons learned from earlier activities.

1. Invest in a variety of development and management strategies to provide farmers with choices in crops that are less vulnerable to climate change.
2. Build the capacity of farmer organizations to contract with consumer groups to reduce risk of innovation (and livelihood vulnerability at the same time).
3. Expand asset-building programs based on lessons from pilot projects.
4. Expand social-capital building programs based on lessons from pilot projects, focusing on cooperative activity in water management, ecosystem service provision, risk reduction, and value-added processing.
5. Invest in agricultural processing activities for less vulnerable crops, such as sorghum (milling and brewing).
6. Invest in apprenticeships for youth, where opportunities for trades and commercial activity are greater.

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