Coffee Resilience in Uganda.
Bridging the gap between farmers and governmental climate services.

Chair of the Committee:
Dr. Corey Gabriel

Members of the Committee:
Dr. Shang-Ping Xie
Ms. Meredith Fish
Mr. Victor Komakech
Dr. Michele Bernardi

Filippo Radice Fossati
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SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

Declaration of Authorship

Filippo Radice Fossati

Master of Advanced Studies in Climate Science & Policy

Scripps Institution of Oceanography, University of California, San Diego

Contact: filipporadicefossati@hotmail.it ; It.linkedin.com/in/filipporadicefossati

Capstone Advisory Committee (CAC) Approval

The following report has been completed under the supervision of the following CAC members, with approval for submittal indicated by the signatures of the CAC members.

Corey J. Gabriel, PhD | Committee Chair

Executive Director, Master program in Climate Science and Policy

Scripps Institution of Oceanography, University of California, San Diego

Victor Komakech | Committee member

Climate change expert at Hanns R. Neumann Stiftung

Michele Bernardi | Committee Member

Former Senior Agrometeorology expert at Food Agriculture Organization of the United Nations

Shang-Ping Xie, PhD | Committee Member

Professor, Climate, Atmospheric Science & Physical Oceanography

Scripps Institution of Oceanography, University of California, San Diego

Meredith A. Fish, PhD Candidate | Committee Member

PhD Candidate, Climate Science, Center for Western Weather and Water Extremes

Scripps Institution of Oceanography, University of California, San Diego

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Summary

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Executive Summary

Working with Hanns R. Neumann Stiftung (HRNS), a German foundation that helps coffee farmers across the tropics increase their business resilience, I had the chance to conduct field research in the district of Luwero, in the central region of Uganda. The main aim of this project is to understand whether or not the Climate and Weather Service (CSW) offered by the Uganda National Meteorology Authority (UNMA), is helping farmers in their seasonal and daily decision-making and coping with natural hazard. The core mission of an efficient CWS is to produce reliable weather and climate forecasting and disseminate this information to users in a timely and understandable manner. Effective climate services should enable climate-smart adaptation strategies that may on one hand, mitigate the impacts of climate-related disasters and on the other, increase farmers' crops yields and thus, profitability.

The coffee farmers I had the chance to interview are all very attentive climate observers. Their deeply-rooted climate knowledge has been established by decades of sensorial observations of all kinds. The farmers' ability to detect a seasonal change is a total body experience: tactile, auditive and visual. It is this indigenous knowledge that historically, farmers have used to plan their activities. Thus, their openness to other external sources of information should not be taken for granted. Nevertheless, according to their stories, the recent climate variability and change has made them lose faith in their own expertise and they are looking for other sources of information. As an alternative source of forecast information, the radio is most available, but farmers seem to have lost trust in it, due to its unreliability and sometimes lack of clarity. As a consequence, during the interviews they have all explicitly asked for help from HRNS.

However, since farmers do not fully understand what a weather forecast really is, Mr. Komakech, climate change expert at HRNS, and I have the feeling that they were mainly blaming the messenger of the forecast rather than the message itself. As forecasts always contain bias, whoever brings them a wrong message may run the risk to lose farmers' trust, HRNS included. Therefore, the realization of a cross-cultural participatory dialogue between farmers and forecasters seems a first crucial step to bridge this communication gap and thus eventually improving the Uganda CWS.

To understand whether farmers were using or not the CWS, and highlighting the key findings, the following paper is broken divided up in four chapters. After outlining assumptions, data and methodology, the first chapter provides the reader with an introduction to Uganda with a description of its geography, climate and economy with a focus on the coffee sector, Uganda's most important cash crop. The last section of this chapter gives a brief overview on the climate variability and change this country has been experiencing and local climate projections.

The second chapter starts with a short explanation on the importance of weather and climate services particularly for countries whose economy highly depends on rainfed agriculture. Successively, since the lack of reliability and clarity seem to be main cause of farmers' estrangement from weather forecast, in the second part of this chapter the paper gives a description of the complexity with which UNMA creates and disseminate the forecasts over Uganda whit the identification of potential inefficiencies.

In the third chapter, this capstone aims to describe the Uganda historic climate pattern and change of the district of Luwero by mainly using farmer's knowledge reported during interviews. The purpose is to outline farmers' need of climate and weather information by first highlighting their way of reading the weather, far from our weather forecasting systems, and thus essential for understanding how to start a cross-cultural climate dialogue. The last part of this chapter tries to identify the potential barriers that could explain farmers' criticism towards weather forecast, by first detailing how UNMA disseminates seasonal outlook in the district Luwero and farmers' perception of the service provided.

The aim of the fourth chapter is to summarize all the potential mechanisms that may block farmers from using climate and weather forecasts and suggesting organizations such as HRNS, as a focal point to bridge the communication gap between farmers and forecasters and thus improving the Uganda climate and weather services.

Assumptions, data and methodology

Before discussing the data and methodologies used for the development of this report, it is important to provide some details on the context in which HRNS works. While I had the chance to interview a few smallholder households, farmers who own a very tiny piece of land where they produce a mix of cash and staple crops, HRNS works intimately with a large number of these farmers, allowing HRNS to validate the interviews herein. HRNS's relationship with the farmers also helps to understand the background of the farmers I interviewed, which may further credit the outcome of this study.

The Foundation has been working in this territory for over fourteen years for the realization of the Uganda Coffee Farmers Alliance (UCFA), a business network that currently supports about 60,000 farmers. UCFA is a pyramid-shaped organization where at the bottom of it, village groups of 20-30 farmers are organized in Producer Organizations (PO) (figure 1). Farmer field schools to increase coffee productivity typically occur at this level. POs are thus grouped together in Depot Committees (DC), where operations such as logistics, quality control and marketing are implemented. Coordination, market access and code of conduct are defined at UCFA level, where all DCs are bundled.

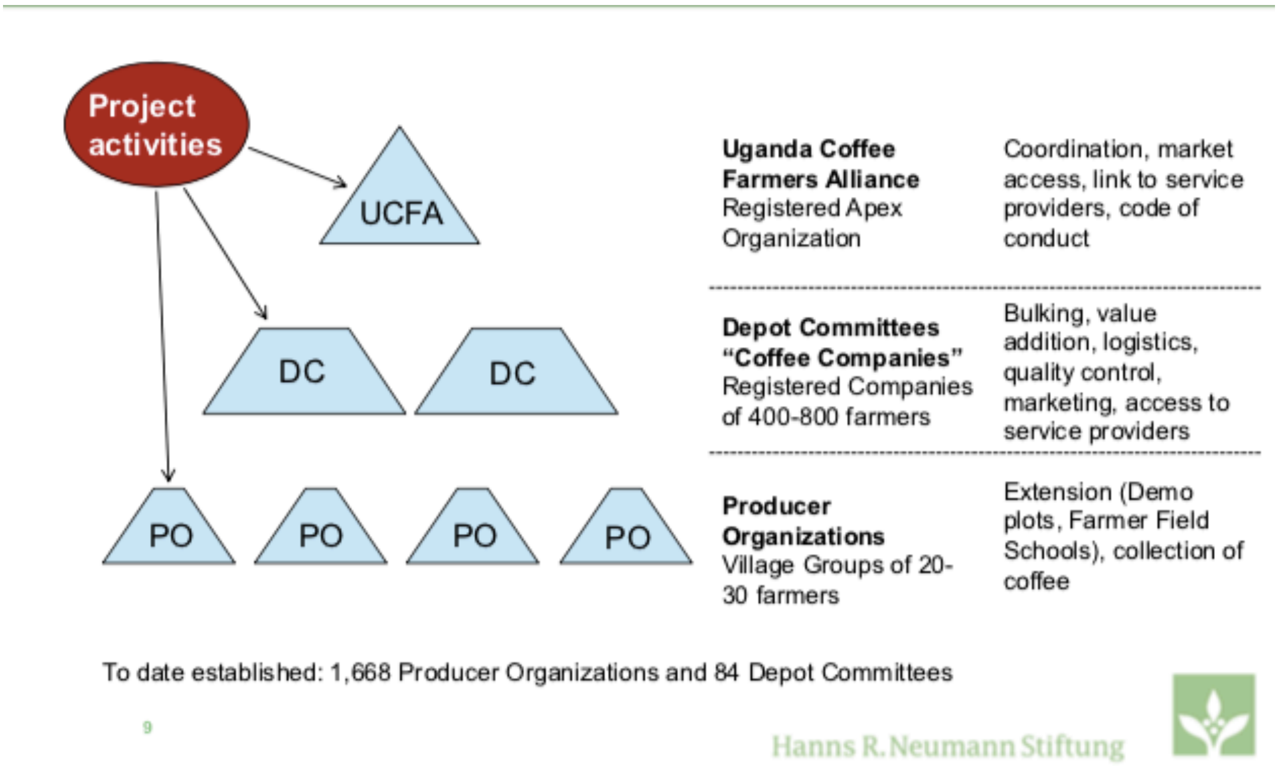

Figure 1 – Structure of the UCFA. Source: HRNS

This capstone has been conducted in the district of Luwero, set in the central region of Uganda, where HRNS has been working with 2 DCs that includes a total of 1280 smallholder farmers. More specifically, the farmers' interviews have taken place in two subcounties, Butuntumula and Katikamu, where HRNS is working with respectively 620 out of 5,249 households (12%) and 660 out of 5,865 households (11%), respectively. In Luwero, HRNS, in partnership with the International Institute of Tropical Agriculture (IITA), is working under the project *Feed the Future Alliance for Resilient Coffee*[1] (ARC), financed by the United States International Development Agency (USAID). The aim of it is to help farmers engaging in agriculture practices to improve profitability and resilience to climate hazards such as, the recent devastating drought that have hit the Luwero region.
Mr. Komakech and I had an interview with Mr. David Mukasa from IITA.
The Annex 2 reports the first IITA results as well as a photo voice story, to report the climate adaptation work IITA and HRNS have done in this region of Uganda.

To understand the way UNMA produces and disseminates weather and climate forecast in Uganda, described in the second chapter, I have combined a literature review and the interviews with officers of different Uganda government authorities such as the Uganda National Meteorological Authority, The Luwero Natural Resources Department and the Uganda Coffee Development Authority.
The goal of these interviews was to understand the complexity and potential barriers of climate and weather service, and whether and how seasonal and weather forecasts were already discussed within workshop sessions between extensionist of the agriculture department and farmers.
To understand so, the following government personnel have been interviewed:

1. Kalema Abubakar, weather analyst at the Uganda National Meteorological Authority.
2. Gateese Teopista, head of the Luwero district Natural Resources Department.
3. Ntwatwa Douglous, Agriculture Extensionist Officer of the Butuntumula subcounty
4. Mathew Kwikiriza Katash, Luwero Regional Officer of the Uganda Coffee Development Authority (UCDA)

[1] https://www.hrnstiftung.org/project/feed-the-future-alliance-for-resilient-coffee/

Moreover, to identify the possibility that weather and climate forecast discussions were already occurring in Butuntumula, as declared by Mr. Ntwatwa Douglous, Mr. Komakech and I have interviewed Mr. Kibalama John, member of the Butuntumula DC. Finally, a literature reviewed was completed to have a better understanding of the importance of an efficient weather and climate service, where reliable seasonal outlook and weather forecasts are disseminated in a country in a timely and understandable manner to improve farmer profitability and ability to cope with natural hazards.

For the development of the third chapter, the interviews of four farmers were used where they reported the climate, natural variability and change of the region. In these interviews the farmers expressed their openness to receive other sources of weather information as well as spoke of the smallholders' lack of trust of the radio weather/climate forecast. To conduct the interviews, I would read the questionnaire while Mr. Komakech would simultaneously translate to the local language, Luganda. The farmers' responses were then translated by Mr. Komakech from Luganda to English, to allow me to fill out the questionnaire. All interviews were recorded for refining details afterwards. The field excursion was photo reported. The Annex 1 reports the structure of the all interviews.

The list of farmers is as follows:

1. Nalugooti Gertrude Musoke, 32 years old. Katikamu subcounty, DC extensionist
2. Ssekandi Daniel Godfrey, 50 years old. Katikamu subcounty, DC extensionist
3. Bazannyanengo Alooni Kiyaga, 63 years old (Farmer). Katikamu subcounty, The Chair of the DC committee
4. Ssalongo Kigongo Fred, 53 years old. Butuntumula subcounty

Since three out of four farmers are part of the DC board of the Katikamu subcounty, they had the chance to give me a wider overview of what other smallholders think about the weather forecast provided by the radio and their willingness to use a different source of information in addition to their own knowledge. All farmer's descriptions have been deepened with a literature review and the use of data coming from the FEWS NET established by the Food of Agriculture Organization website[2]. This dataset provides the user with a ten-days rainfall time-series at the district level for the period 1995-2019.

[2] http://www.fao.org/giews/earthobservation/country/index.jsp?lang=en&code=UGA#

1. Uganda

1.1 Geography and Climate

Uganda is a landlocked country situated on the East Africa plateau and it lies within the equatorial climate zone, between 1˚ S-4˚N latitude and 29˚E-34˚ longitude. Starting from the North and going clockwise, Uganda shares its borders with South Sudan, Kenya, Tanzania, Rwanda and Democratic Republic of the Congo (Figure 2). The southern part of the country is mainly bordered by Lake Victoria, the largest freshwater lake in the tropical regions, having a surface area of 70,000 km^2. Lake Victoria also borders Kenya and Tanzania (Lighthill et al., 1981).

Figure 2 –Map of Uganda. Source: United Nations, Department of Public Information – Cartographic Section

Although Uganda lies astride the equator, the complexity of the topography and the presence of a multitude of rivers and lakes (Nsubuga et al., 2014) are all factors that allow the climate to differ substantially across the country. For instance, the true equatorial climate–characterized by evenly distributed rainfall in the range of 2,000–2, 500 mm per year and constant monthly temperatures in the range of 24˚C–27˚C is limited to some islands in Lake Victoria. This could be due to the lake being an important source of water vapour that enhances the precipitation processes in the region. By contrast, a tropical savanna and a semi-arid to arid season characterize the northern part and north east area of Uganda, respectively. The northern region records rainfall ranging from 750mm to 1500mm per year with temperatures in the range of 24˚C to 30˚C, whilst the north east region averages rainfall amounts less than 750mm with temperatures that can exceed 30˚C (Bakama B. BakamaNume, 2010).

Temperatures, as well as rainfall, change throughout the year over Uganda. Starting with temperatures, June, July and August (JJA) are the coolest months while December, January and February (DJF) and March, April, May (MAM) are the warmest (figure 3) (Nsubuga et al., 2017; Government of Uganda, 2015).

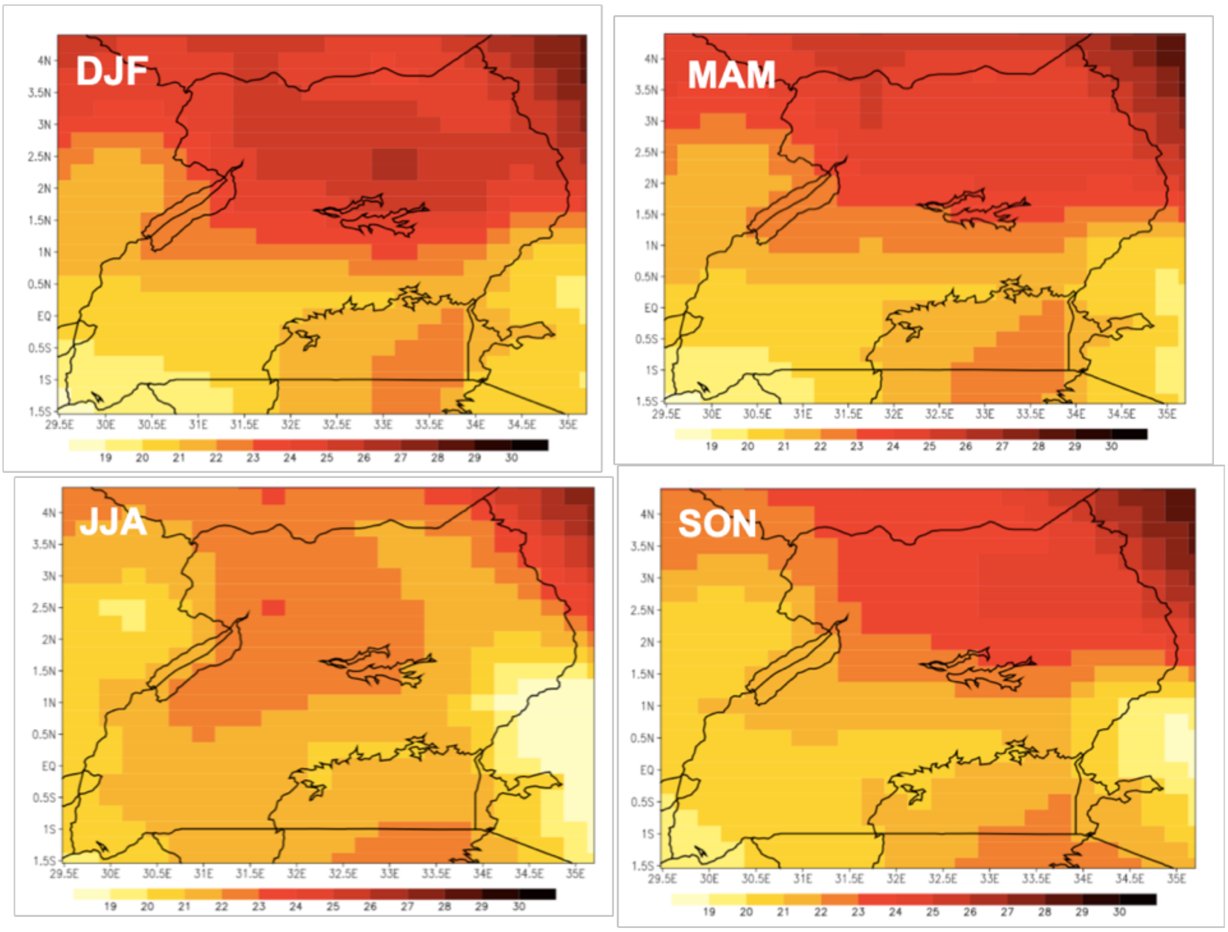

Figure 3 - average (1986 -2005) seasonal near-surface (2 m above surface) temperature (˚C) as captured using ERA Interim Reanalyisis data. Source: Government of Uganda, 2015

Rainfall is vital for a country whose economy is mainly based on rainfed agriculture, coffee production included. As previously mentioned, the spatial and seasonal distribution of rainfall differs substantially across the country depending on multiple influencing factors. The latitude effect seems being one of the main driving factors (Nsubuga et al., 2014; Nsubuga et al., 2017; Bakama B. BakamaNume, 2010): the constant heating of the equatorial sun generates a low-pressure region called Inter-tropical Convergence Zone (ITCZ) where the air mass rises convectively, condenses and eventually falls as precipitation often with heavy precipitation rates (Figure 4) (Nicholson et al., 2018).

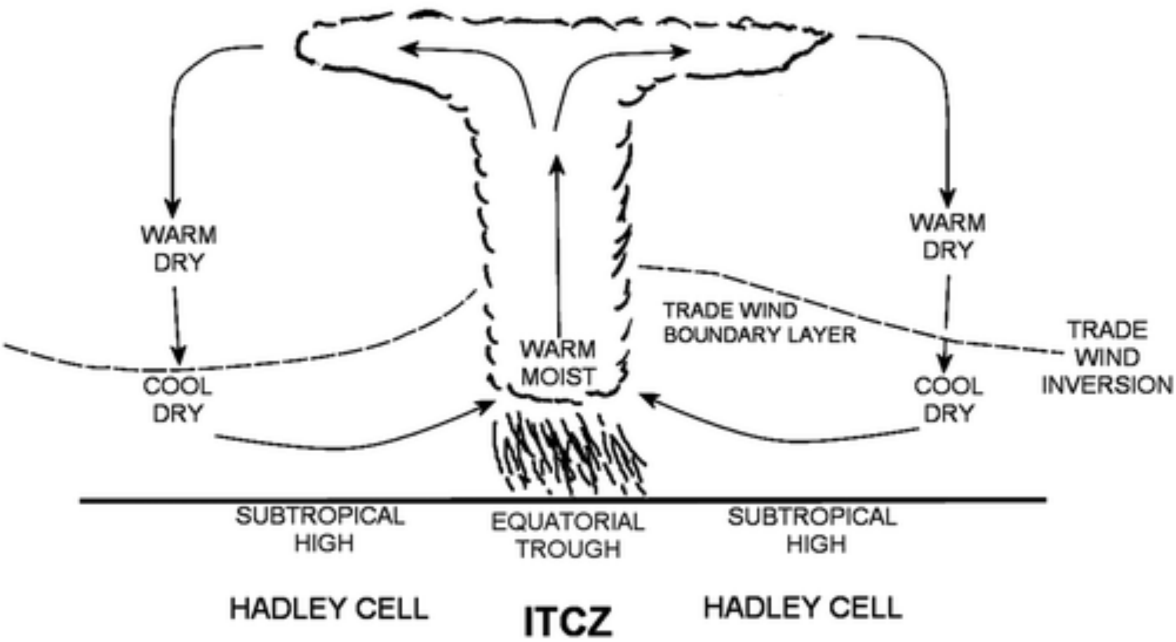

Figure 4 – Simplified Scheme of the ITCZ. Source Nicholson, 2018)

The ITCZ migrates north and south following respectively the boreal and austral summer, respectively, and thus causing the bimodal rainy seasons that characterized the central, western and eastern regions of Uganda. The first and most abundant of the rainy seasons starts in March and ends in May (MAM), whilst the second goes from September to November (SON) (Figure 5) (Nicholson et al., 2018).

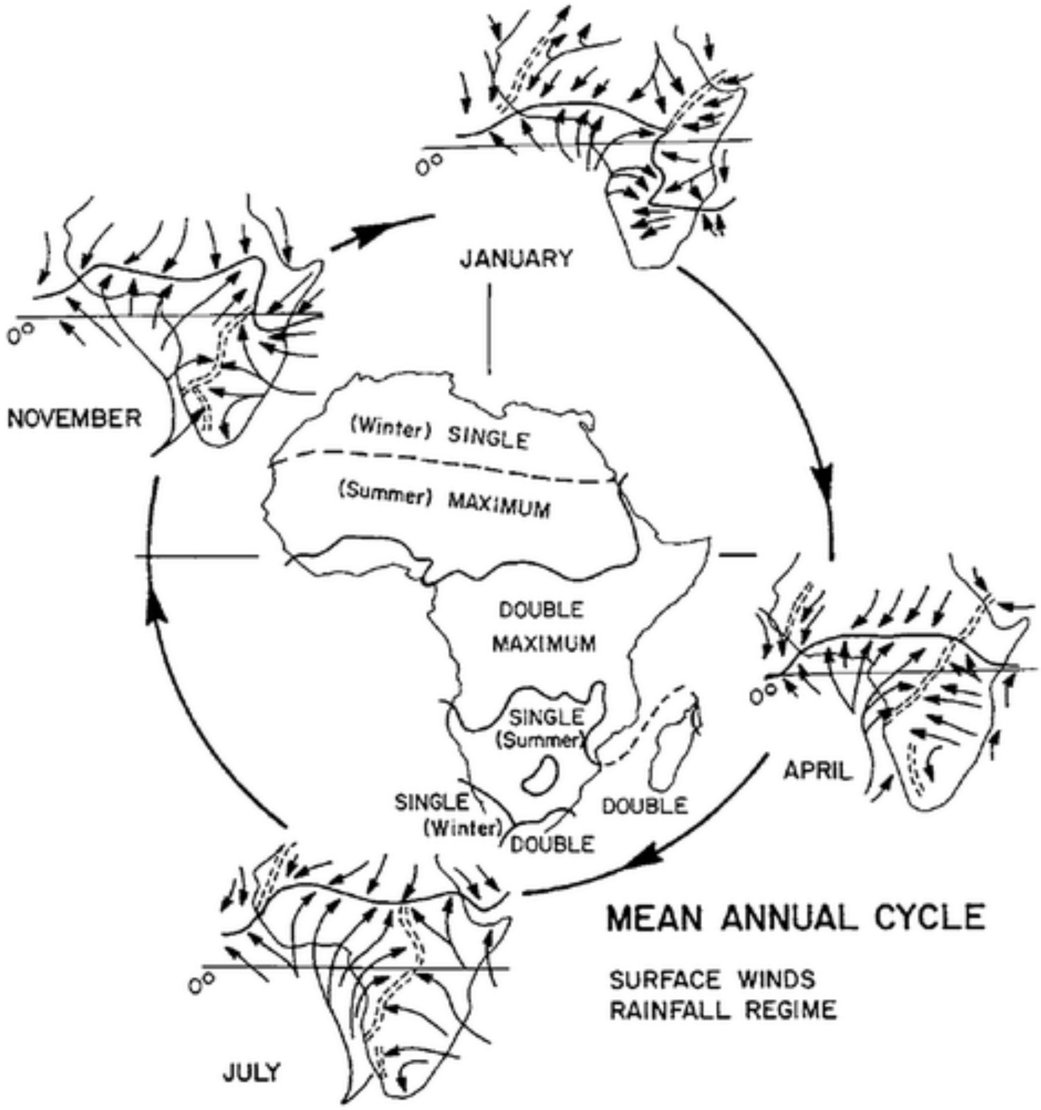

Figure 5 – Location of the ITCZ throughout the year. Source: Dhonneur 1974; Nicholson, 2018

However, since 1940 the total amount of yearly rainfall has always been highly variable. Nsubuga et al. (2014) assessed observational data from 36 stations, concluding that the regional total rainfall for the period 1940-2009 has ranged from years of normal and above-normal rainfall to periods of below-normal rain (figure 6). The same study shows dry periods in the 1940s, between the end of 1960s and beginning of 1970s, and 1980 through the beginning of the 1990s. Wet periods were identified in the early 1950s, throughout the 1960s, end of the 1970s and towards the end of the 1990s.

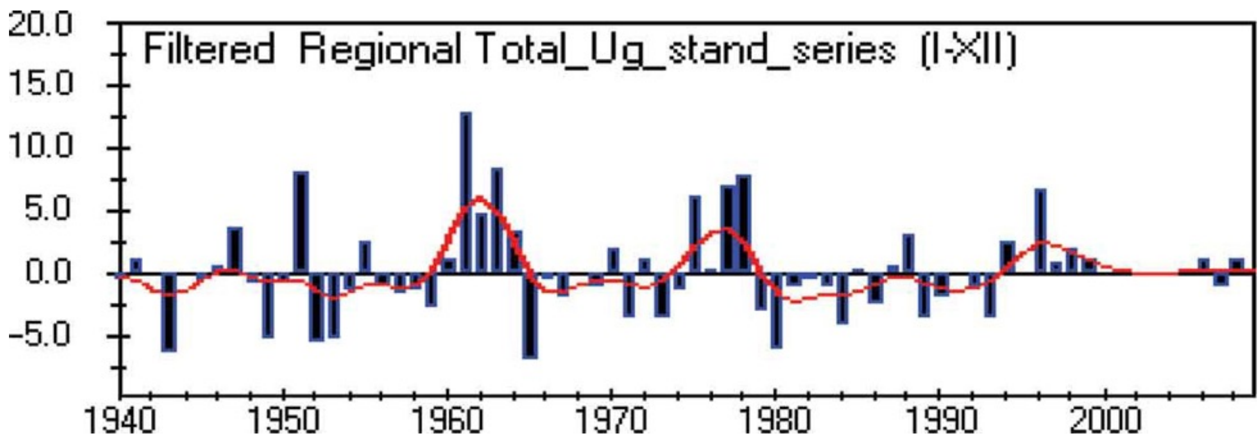

Figure 6 - Total rainfall region 1940-2009. Source: Nsubuga 2014

Nsubuga et al. (2014) also outlines the internal climate variability causing dry and wet periods, may be linked to different climate-ocean interactions such as the cyclical oscillation of sea surface temperatures in the tropical Pacific Ocean, termed El Niño Southern Oscillation (ENSO). ENSO generates a change in temperature, precipitation and the atmospheric circulations locally and worldwide through a global teleconnection pattern (Box 1 for more details). The peak of ENSO generally occurs in December, January and February, during this time Uganda experiences a dry spell compared to the usual occurrence of the first rainy season while more abundant rainfall can be recorded during the second rainy season, starting in August. During La Niña events the opposite pattern may occur (Nsubuga and Rautenbach, 2017; Schreck et al., 2004; Nicholson,1996).

Box 2 – El Niño Southern Oscillation, an important example of ocean-climate interaction

The Pacific Ocean as a whole plays a key role in Earth's climate as a shift in sea surface temperature (SST) can have repercussions all over the world. In normal or neutral conditions, the Western Pacific Ocean is characterized by a region of low-pressure, while a high-pressure area can be found in the Eastern Pacific Ocean. A pressure gradient builds due to a SST difference between the two sides of the Pacific Ocean, with the western side–known as the Great Pacific Warm Pool, is warmer than the eastern. The consequence of the resulting pressure gradient is the *Walker Circulation*: above the low-pressure area an air mass rises convectively, spreading east once it hits the tropopause to then sink in the eastern Pacific and ultimately connecting the circulation. The resulting *trade winds* blow westward all along the equator–from the surface high pressure area to the low-pressure region. The SST difference between the two sides of the Pacific Ocean are enhanced by two mechanisms: on the western side, the pressure impressed by the trade winds along the equator piles up warm water while simultaneously forcing a deeper thermocline, a boundary placed between the warmer mixed layer near the surface and the colder and deeper water. On the eastern side, the trade winds blow offshore generating a wind-driven upwelling system and shoaling the thermocline, by upwelling cold water from the deep ocean. The interaction between thermocline depth and atmospheric circulation enhance the Walker Circulation. Aloft the pressure gradient is reversed. In normal conditions, the Western Pacific Ocean is characterized by abundant rainfall, while the Eastern Pacific is typically drier due to the sinking air mass.

However, for various reasons, every 5-7 years the trade winds weaken and redistribute the warm surface water from the western Pacific to the central-eastern Pacific Ocean. One proposed mechanism for initiating ENSO conditions are the strengthening of equatorial *Kelvin Waves*, a wave generated due to the Earth's rotation which propagate eastward along the equator with a speed of 3m/s. Moreover, the weakening of the trade winds and, as consequence, the strengthening of the Kelvin waves reduces the equatorial upwelling system and deepens the Eastern Pacific thermocline increasing SST. The resulting increase in SSTs in the central-eastern Pacific Ocean generates a positive feedback, termed the Bjerknes feedback, which reinforces the initial anomaly. These changes throughout the tropical Pacific induce an eastward shift to the region of deep convection. The National Oceanic and Atmospheric Administration (NOAA) would declare this condition, known as the "*El Niño phase*", when the SST of a specific region in the central Pacific Ocean, the Niño 3.4 region, records a, "five consecutive 3-month running mean anomaly above the threshold of + 0.5 ˚C"[1]. El Niño events partially end due to the refraction of kelvin waves off of South America, as they are reflected westward redistributing warmer water to the western Pacific and begin to reinforce the upwelling system in the eastern Pacific to reestablish the original circulation.

Westward traveling off equatorial waves, named *Rossby Waves,* can also reverse the warming effect. As soon as the trade winds re-strengthen, “normal conditions” can be reestablished. Yet, it often happens that a year or two after an El Niño phase, trade winds can become more vigorous than usual and the normal condition can enter in a new different phase: *La Niña.* According to NOAA, La Niña occurs when the SST of the Niño 3.4 region records a “five consecutive 3-month running mean anomalies below the threshold of - 0.5 °C”.

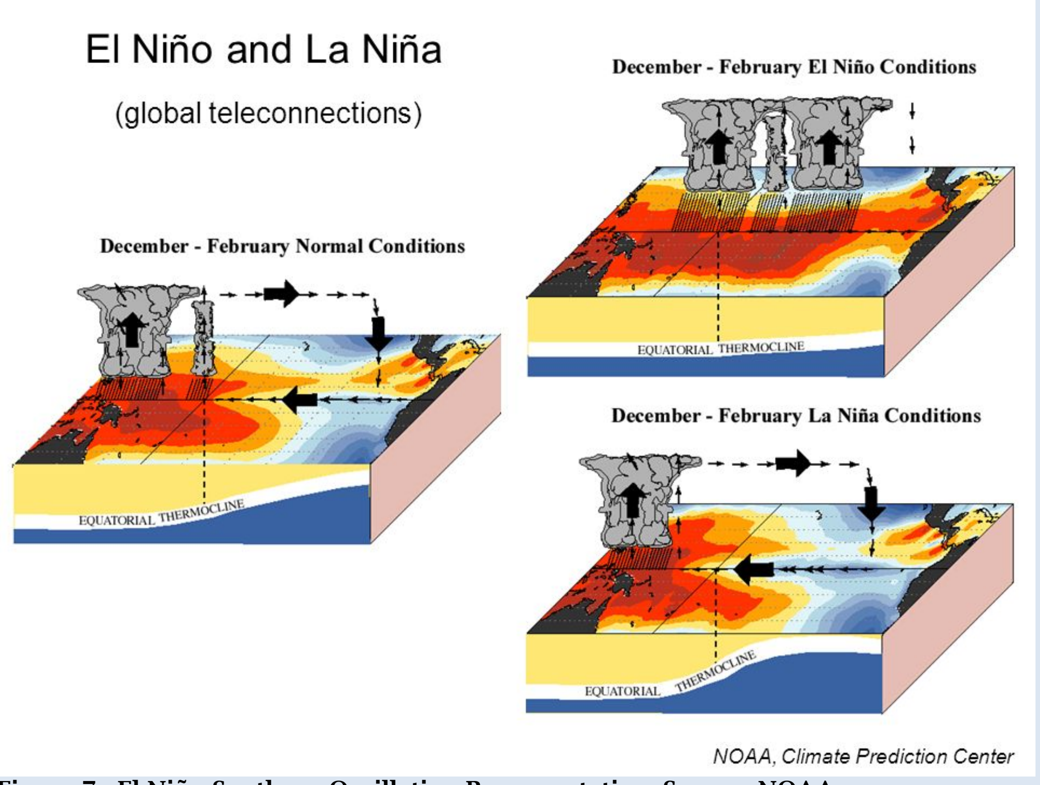

Figure 7 - El Niño Southern Oscillation Representation. Source: NOAA

The *ENSO or El Niño Southern Oscillation* then, is the oscillation of the Pacific Ocean between neutral conditions, El Niño and La Niña phases. These alterations of the tropical Pacific region generate a change in temperature, precipitation and the atmospheric circulations locally and worldwide through teleconnection patterns. For instance, during the El Niño phase, the western side of South America, mainly Peru and Ecuador, record heavy flooding events, while areas such as Indonesia or Australia are characterized by intense drought. The oscillation of this phenomenon can even affect the hurricane season within the central Atlantic Ocean as it is more likely that a hurricane can develop during a La Niña phase rather than neutral or El Niño phases. During El Niño Uganda experiences a dry spell compared to the usual occurrence of the first rainy season while more abundant rainfall can be recorded during the second rainy season, starting in August. During La Niña events the opposite pattern may occur. Therefore, understanding whether this type of natural variability could be exacerbated by climate change is particularly relevant.

1.2 Economy

The 2018 Human Development Index (HDI), an index that combines life expectancy, education and income per capita, ranks Uganda[3] 162th out of 189 countries. In Uganda, the life expectancy at birth, the expected years of schooling, the mean years of schooling and the gross national income per capita are respectively 60.2 years, 11. 6 years, 6.1 years and 1,658 $ (Purchasing Power Parity).

According to the 2014 National Population and Housing Census (UNHS, 2014), Uganda's population is 34.6 million people with a recorded 3% annual population growth rate between 2002 and 2014. The Uganda Bureau of Statistics (UBS) has declared a current population of about 40.1 million[4]. The 2018 UBS statistical report[5] (UBS , 2018), has declared that 53.6% of the population is less than 18 years while the population older than 60 years account for only 3.7%. The 2016 Uganda Demographic and Health Survey (UDHS, 2016) reports a total fertility of 5.4 children per woman and the 2017 United Nation Development Program Uganda Annual report (UNDP, 2017) has declared a life expectancy at birth of 62.2 for male and 64.2 for female, slightly higher than the 2018 HDI. The 2016 UDHS reports infant mortality and the under five-mortality rate of 43 and 64 deaths per 1,000 live births respectively. According to the World Health Organization the risk of a child dying before being five years old is as average in Africa and in Europe 74 and 9 per 1000 live births respectively[6].

Uganda has a poverty rate of 20% (UBS , 2018), meaning that about 8 million people still live below the national poverty line ($1.90 PPP per day). However, the 2018 PWC Uganda economic outlook[7] forecasts an acceleration in the real Gross Domestic Product (GDP) growth between 5% to 7% during the period 2018-2022, in which, the agriculture sector may play a big role. According to the World Bank Uganda Economic Update 2018 report[8] (World Bank, 2018), the agriculture sector employees 70% of the population and generates 25% of the Uganda GDP. In 2017, coffee was Uganda's "leading commodity export" and the value of this industry has recorded an increase of about 50% passing from US $371.7 million in 2016 to US $555.5 million in 2017. This result accounts for 2.1% of the total GDP if other cash crops such as cotton, tea, cocoa, tobacco and sugar cane are considered (UBS , 2018).

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[3] http://hdr.undp.org/en/2018-update
[4] https://www.ubos.org
[5] https://www.ubos.org/wp-content/uploads/publications/01_2019STATISTICAL_ABSTRACT_2019.pdf
[6] https://www.who.int/gho/child_health/mortality/mortality_under_five_text/en/
[7] https://www.pwc.com/ug/en/assets/pdf/ug-economic-outlook-2018.pdf
[8] http://documents.worldbank.org/curated/en/678231542382500879/Uganda-Economic-Update-12th-Edition-Developing-the-Agri-Food-System-for-Inclusive-Economic-Growth

However, Uganda is the second largest coffee producer in Africa after Ethiopia, and in 2018, 4.9 million 60 kg bags (294,000 metric ton) were produced, accounting about 27% of the total Africa coffee production of 17.8 million 60 kg bags (1,068,000 metric ton) (International Coffee Organization[9]).

Robusta coffee has accounted in 2017, for about 75%, 220,5 tonnes, of the Uganda annual production, and it has been mainly produced in the Central Part of Uganda. In the same year, Uganda has produced 73,5 tonnes of the Arabica coffee, also known as *mountain coffee*, mainly on the eastern borders with Kenya and in south-western border with Rwanda (Figure 8) (UBS, 2018).

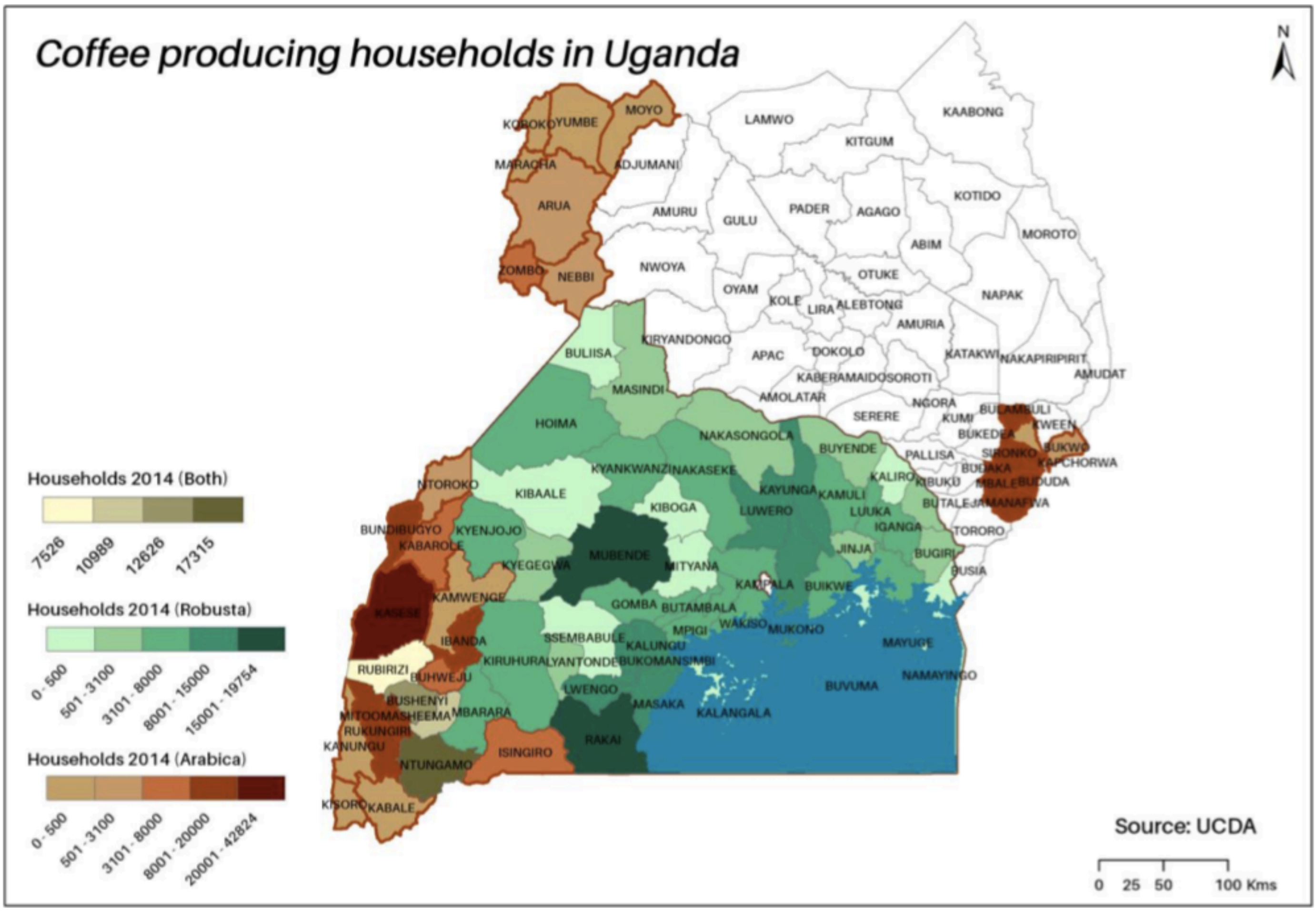

Figure 8 - Distribution of the coffee production within the Uganda territory. Source: UCDA

[9] http://www.ico.org/trade_statistics.asp

As it is going to be briefly described in the next session, Uganda's coffee industry and therefore Uganda's economy, is already threatened by natural climate variability and change. Uganda's Second National Development Plan (2015 – 2020)[10] highlights that climate change will likely affect its key economic sectors, coffee included. Thus, building climate resilience is a key element of Uganda's Plan. Yet, one of the main barriers for defining efficacy and proactive adaptation strategies is the high level of uncertainty in terms of climate projections Uganda has been and is expected to experience. According to different studies (Nsubuga and Rautenbach, 2017; Rowell and Booth, 2015), East Africa has recently been victim to devastating droughts, whilst the majority of climate models have predicted an increase of rainfall, leading to a contradiction named the East African Climate Paradox.

The final part of this chapter gives a short overview of recent climate trends and future projections in Uganda.

[10] https://consultations.worldbank.org/Data/hub/files/consultation-template/materials/ndpii-final11.pdf

1.3 Climate Trends and projections

The lack of observational data makes it hard to understand whether there has been any changes in the climate pattern of Uganda in the past decades due to climate change. Additionally, the eastern part of Africa is a geographical area affected by multiple global-scale natural variability on a variety of time scales. The noise created by ocean-climate forcing can also make the detection of a trend harder. For instance, as explained in the first section of this chapter, ENSO may impact rainfall patterns in this area every 5-7 years. But it is not the only one forcing pattern. Another inter-annual ocean-climate forcing which may affect the rainfall pattern of eastern Africa is the Indian Ocean Dipole (IOD). The IOD corresponds the oscillation of sea-surface temperatures in the western part of the Indian Ocean. When the western Indian Ocean becomes warmer than the eastern one, the IOD enters in a positive phase, which should correspond to an increase of rainfall in Africa. Instead, when it is colder in the western Indian Ocean, a negative phase persists and precipitation may increase or decrease in the region (Nsubuga and Rautenbach, 2017; Schreck et al., 2004; Nicholson,1996)

Nonetheless, some impacts of climate change have been detected. In terms of temperature, the fifth assessment by the Intergovernmental Panel On Climate change (IPCC) declares that many areas of Uganda have recorded an increase in seasonal mean temperatures in the past 50 years. Over the period, 1960-2008, Uganda has experienced a positive trend in both minimum and maximum temperatures, with nights warming faster than days (Nsubuga and Rautenbach, 2017). The Famine Early Warning System Network (FEWSNET) has estimated that for the period 1975-2009, the warming has been greater than 0.8°C during both March-June and June-September. The same study concludes that for the period 1960-2009 temperatures have increased by up to 1.5°C across the majority of Uganda, with a warming rate of 0.2°C per decade and that a warmer climate may amplify the impact of decreasing rainfall and recurrent drought and may have a severe impact on food security (FEWSNET, 2012). Several studies agree on the fact that Uganda has recorded a decrease in precipitation. FEWSNET indicates that the period 2000-2009 has recorded on average 8 percent lower rainfall than the ones Uganda has experienced over 1920-1969. Moreover, this decrease in rainfall has appeared in March-June, when Uganda receives most of its rain, and June-September.

In terms of climate projections, the fifth assessment by the Intergovernmental Panel on Climate Change (IPCC) compares a scenario with a moderate level of mitigation of greenhouse gases with a business as usual scenario, defined as Representative Concentration Pathway 4.5 (RCP 4.5) and Representative Concentration Pathway 8.5 respectively. In both scenarios the IPCC has compared the change in seasonal rainfall and temperature for 2046 – 2065 relative to the period 1985 – 2005.

In terms of temperature, under the RCP4.5 scenario, Uganda may record an increase of 2˚C in 60 years from present and temperatures could rise more during the MAM and JJA seasons in comparison to DJF. Comparatively, in the RCP8.5 near-surface temperatures may increase 3˚C in 60 years (Figure 9, 10).

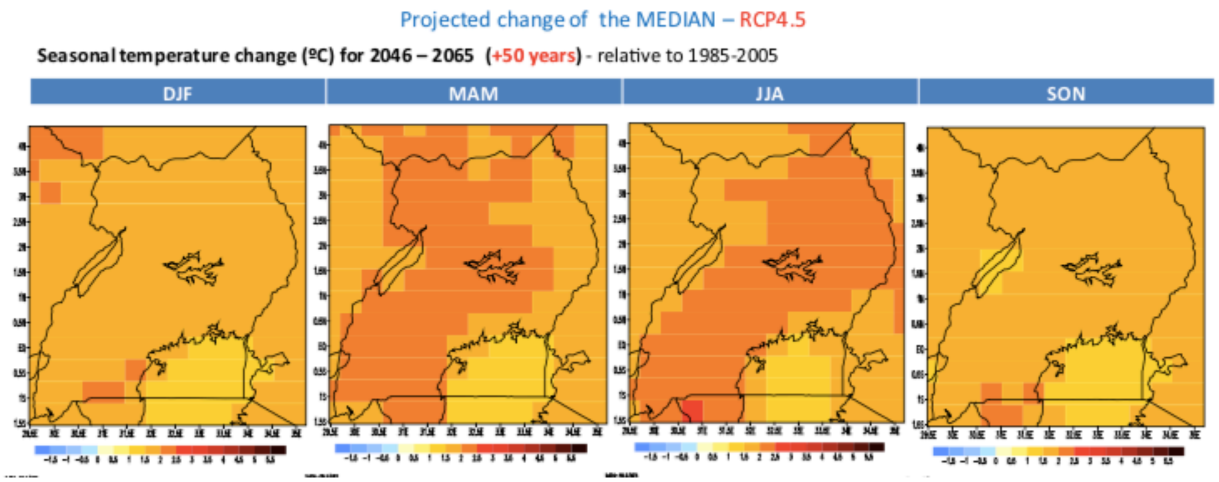

Figure 9 - Seasonal Temperature Change Projection. RCP4.5. Source: Nsubuga and Rautenbach, 2017

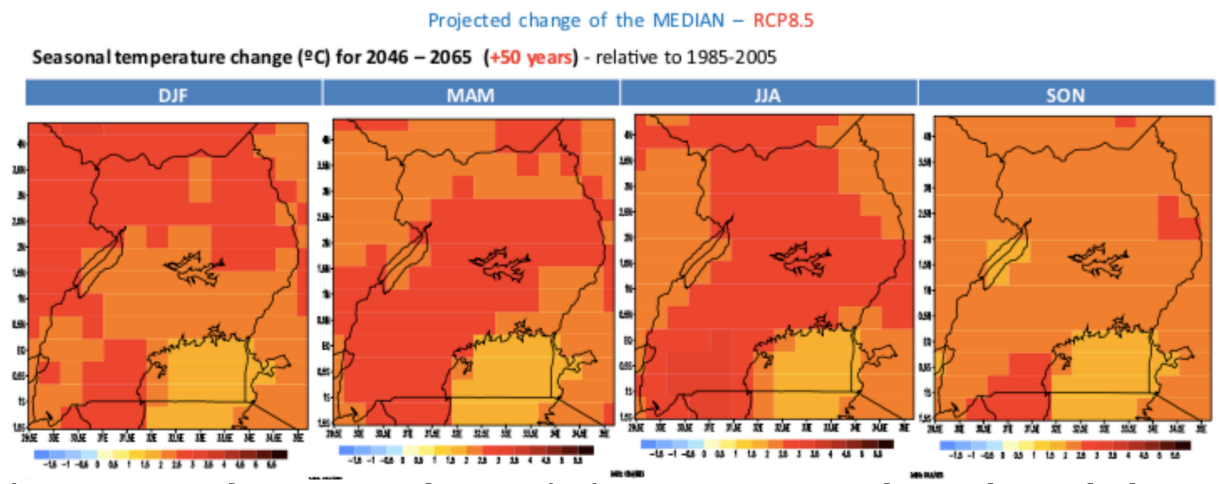

Figure 10 - Seasonal Temperature Change Projection. RCP8.5. Source: Nsubuga and Rautenbach, 2017

In terms of rainfall (Figure 11,12) the total annual amount will differ slightly compared to the control period in both scenarios. For instance, the RCP4.5 scenario projects a change in the range of +/- 10%. While uncertain, this does not rule out, a potentially dramatic spatial and seasonal change that may occur in most of the Ugandan territory. Indeed, the RCP4.5 scenario reports drier conditions over all of the country apart from the northwest area, which may record higher levels of rainfall. Furthermore, according to the RCP4.5, the DJF season may experience an increase in precipitation, up to 100% from the present, whilst MAM may record a decrease. As we will see in the third chapter, the seasonal distribution of rainfall is vital for farmers' activities. Thus, all these seasonal changes may cause a dramatic impact in farmers' livelihood and stability of the region.

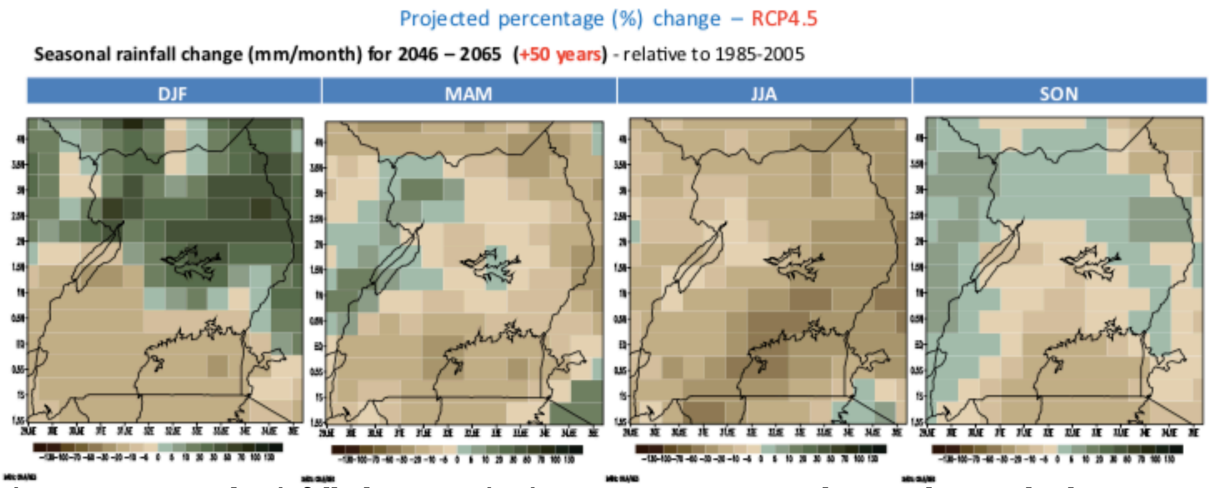

Figure 11 - Seasonal Rainfall Change Projection. RCP4.5. Source: Nsubuga and Rautenbach, 2017

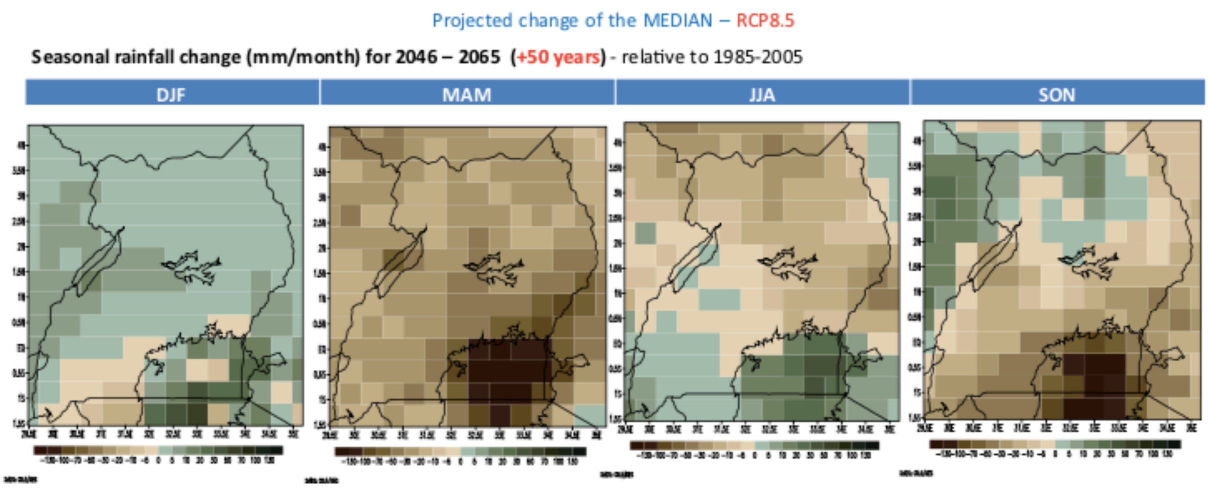

Figure 12 - Seasonal Rainfall Change Projection. RCP8.5. Source: Nsubuga and Rautenbach, 2017

2. Climate and Weather services for climate resilient development

The opening part of this chapter briefly describes the importance of climate and weather services (CWS) for the economy of countries, such as Uganda where one fourth of the GDP depends on rainfed agriculture. The second and third sections of this chapter, report how the climate and weather forecasts are produced and disseminate in Uganda, respectively. The aim of this chapter is to outline potential inefficiencies that may partially explain the criticism of this service raised by farmers in the third chapter of this capstone.

2.1 The importance of effective weather and climate services

Optimal climate and weather services is related to the ability to produce reliable weather and climate forecasting and to disseminate this information to users in a timely and understandable manner (World Meteorological Organization[11]). Effective climate services should enable climate-smart adaptation strategies that may mitigate the impacts of climate-related disasters and increase crops yields and profitability. The *handbook on climate information for farming communities* (Bernardi, 2019), recently published by FAO, clearly distinguish the key climate variables farmers need to promptly receive: onset of the monsoon, forecasted total rainfall and intra-seasonal rainfall distribution across all crops' growth stages (figure 13). If this climate information is reliable, provided at the right time and understandable by users, it is more likely the farmers may plan a series of activities that can protect them from climate hazards and increase crops yields.

As outlined during the farmers' interviews, the pre-planting and planting practices are important for cash crops, such as coffee, as they may be changed according to the rainfall forecast (figure 14). For instance, if the amount of rainfall forecasted is considered above average, farmers need to implement measures to increase the soil drainage, engaging in mitigation activities, such as digging trenches. By contrast, if the amount of rain forecasted is below average water retention measures should be taken. In addition, the quantity and quality of fertilizer, as well as, the timing of its application depends on the forecast of the rainfall distribution during the different crop growth stages; even the timing of

[11] https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services

pesticide application depends on the distribution of rainfall during the crop growth stages. To further increase the effectiveness of fertilizers and pesticides, manuals of these products suggest finer weather information, such as local wind speed. For example, if during application the wind speed is stronger than the suggested value, the pesticides may disperse into the surrounding environment causing multiple negative side effects. Apart from reducing the capability of the pesticide to eliminate the infestation, the wrong application may affect farmers both economically and health-wise.

KEY DECISION POINTS	KEY CLIMATE VARIABLE THAT INFORMS THE DECISIONS
Sowing period	Onset of monsoon
Choosing of crops/crop variety	Total rainfall forecast and its intra-seasonal distribution
Irrigation management – in terms of timing of irrigation and quantity of water to be applied	Total rainfall and its intra-seasonal distribution
Resource Use Allocation – both labour and finance	Total rainfall forecast and its intra-seasonal distribution
Fertilizer application – the quantity and type of fertilizer as well as the timing of application of fertilizers on crops	Forecast of the distribution of rainfall across the crop growth stages
Timing of pesticide application	Wind direction, wind speed and distribution of rainfall across the crop growth stages
Time of Harvest	Forecast of the distribution of rainfall during the crop maturation stages

Figure 13 - "Key decision points impacted by climate information". Source: Bernardi 2019

IF RAINFALL SHOULD BE HIGH	IF RAINFALL SHOULD BE LOW
» Measures to affect drainage of excess rainfall » Choice of higher water requirement food or cash crops with particular desirable traits and large potential yields (in quantities and economic return) » Choice of inter-cropping two or more crops in the same plot, known to be advantageous with adequate rainfall » Planting in narrow rows, with high seed densities and initial fertiliser rates to maximise production » Dry planting prior to the onset of rains	» Land preparation and pre-plant tillage oriented towards water retention of all rainfall » Lower water requirement crops which offer insurance for the family food supply » Mono-cropping to ensure at least subsistence level production if rainfall should be low » Wide rows (lower densities), reduced seed and fertiliser rates for more assured and cost-effective food production with limited water » Planting delayed until the soil contains sufficient water to germinate and support seedlings through possible early season dry spells.

Figure 14 - "Key decisions in pre-planting and planting periods". Source: Bernardi 2019

Thus, timely and reliable seasonal and weather forecasts may make a positive impact in terms of farm management. But these forecasts must be understandable to increase farmers' ability to use this information and combine it with their own expertise to efficiently plan their seasonal and intra-seasonal activities to ensure food security and increase profitability. As describes in the third chapter, sometimes the single statement "above average" or "below average" heard through the radio is not sufficient to allow farmers to make decisions. Especially in a situation where, according to the farmers interviews, smallholder farms, which are impacted by local weather patterns do not always experience the expected forecast.

2.2 Seasonal and weather forecast production

The Uganda National Meteorology Authority (UNMA) is responsible for producing and disseminating weather and climate forecasts, as well as installing and maintaining weather stations. The UNMA agro-meteorology and sensor division is in charge of providing weather advisories to the farming community by using seasonal, monthly and 10-days climate outlook. During the interview, the weather analyst Mr. Kalema Abubakar has explained to me that to produce forecast, UNMA uses a combination of two techniques: statistical forecasting and computer modeling. The former is based on historical trends where forecasters examine historical data to predict future patterns of a variety of variables, such as temperature and precipitation. For the latter, forecasters use complex atmospheric dynamic models tailored with current weather data to predict weather on timescales less than 14 days.

The Great Horn of Africa (GHA) has always been exposed to extreme climate events, such as droughts and floods. In 1996 the Intergovernmental Authority on Development (IGAD) was formed with the goal to create capacity building and mitigate natural disasters in the region. The IGAD Climate Prediction and Applications Centre (ICPAC) is an institution mandated to provide Eastern and Southern African countries with technical assistance in weather and climate forecasting. Due to the lack of financial resources, skilled personnel and infrastructure such as satellites, the UNMA seasonal, monthly and 10-days climate outlook are designed in partnership with the ICPAC culminating for the Greater Horn of Africa Climate Outlook Forum (GHACOF), which is held before the onset of the rainy season. This two-days forum hosted every time in a different country belonging to the Region[12], gathers climate information providers and users from key socio-economic sectors with the aim to assess how large and regional scale circulation processes could affect different sectors of the GHA region, such as agriculture and health. Global and circulation dynamics are then assessed by climate scientists from all GHA countries with help from international climate scientists in a 1-2-week capacity building training workshop that precedes the GHACOF. Furthermore, to properly understand the potential impacts of the forecasts for Uganda, the GHACOF is followed by a one-day workshop in Kampala where scientists, sector experts and head of institutions define the final seasonal outlook, which will be released by the Ministry of Agriculture. Finally, the ICPAC will provide UNMA with an update of the seasonal forecast on a 10-days and monthly basis

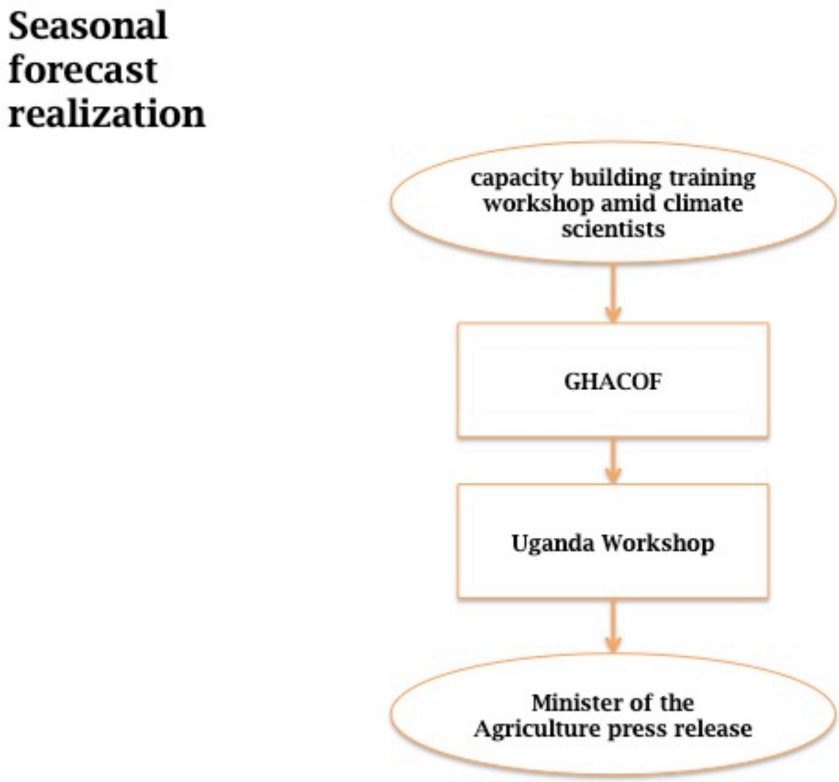

Figure 15 - Processing and dissemination of the seasonal forecast. Source: Mr. Kalema Interview

However, despite the intergovernmental efforts, there are several factors that may prevent UNMA from increasing the reliability of their forecats. For instance, the lack of historic observational data may prevent the statistical forecasting technique

[12] The list of countries participating on this forum is as follow: Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania and Uganda. http://www.wmo.int/pages/prog/wcp/wcasp/rcofs/webpage/GHACOF.html

from having a solid background for future forecasts and the few numbers of weather stations may not efficiently represent all Uganda climatic zones (Mr. Kalema Interview; UNMA, 2015). The 2015 report on the status of weather stations in Uganda (UNMA, 2015), counts 39 weather stations without listing rain gauges, while Mr. Kalema has listed 15 agro-meteorological stations, 12 hydro- meteorological stations, an undefined numbers of synoptic and about 150 rain gauges spread all over the country. By using 39 weather stations as the actual value, if the land area of Uganda is about 200,000 square km (77,422 sq mi) it means that there is an automatic weather station every 5,100 square km (1,970 sq mi). Even though I haven't been told what the optimal density should be, Mr Kalema has reported a need to increase the spatial representation. By looking at figure 16 we can clearly see that weather stations are not equally distributed. There is a higher density in the central region.

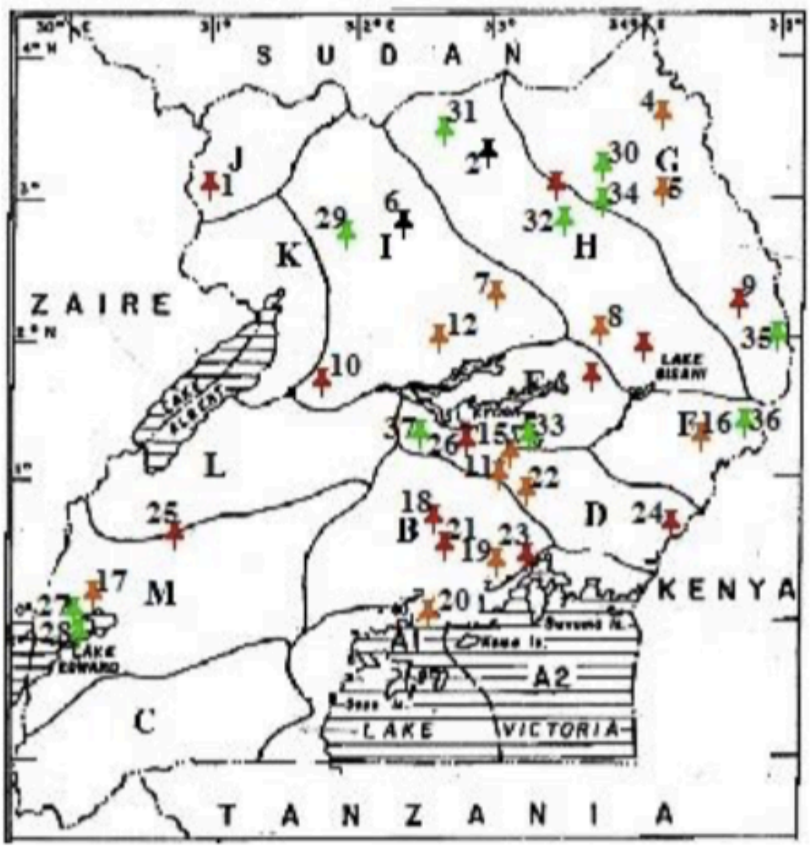

Figure 16 –Maps of weather stations. Legend: red pin = Non-Operational automatic weather stations (AWS); orange pin = AWS with coordinates; Green pin = AWS with no coordinates; Black pin: manual weather station. Source: 2015 UNMA

To fill this lack of observations, other agencies such as The National Agricultural Research Organization (NARO) and the Hydro meteorology Department (HMD) have installed their own weather station. However, it seems that the lack of coordination in terms of exchange of weather information between the three key Government of Uganda organizations - UNMA NARO and HMD – is another driving factor of this collective action "inefficacy" (Irish Aid, 2018).

Finally, the lack of skilled personnel may prevent UNMA to maintain weather stations fully and properly operational. Some of the automatic weather stations present different technical challenges: sensors not well calibrated, vandalism of solar panels and lack of spare weather instruments such as batteries, factors that may keep automatic weather station out of the service (UNMA, 2015).
However, the reliability of the information is just one part of quality of a CWS. Seasonal and weather forecasts need to be distributed in a timely and understandable manner. Thus, the next section assesses the dissemination process.

2.3 Seasonal and weather forecast dissemination

The dissemination of seasonal, monthly and 10-days forecasts follows mainly two different ways. The first and more obvious, even used for the daily basis weather forecast, occurs through media such as radio, TV and SMS. Yet, since in Uganda there are about 60 languages (Mr. Kalema Interview) this type of dissemination may be not as effective as it could be in countries with a less fragmented cultural background. Moreover, the information provided within seasonal outlooks is not always straightforward, particularly for farmers with a low level of literacy. Thus, with the second one, information is directly discussed on field between agriculture officers – extensionist from the Natural Resource Office – and farmers.

However, Uganda is divided in 100 districts across four administrative regions. Each district is divided into sub-counties, parishes and ultimately in villages. Thus, given the high level of bureaucracy, the forecast needs to pass through different stakeholders before landing in farmer's hands, a dramatic inefficiency for a service which should provide information in a timely manner (Figure 17). First off, UNMA delivers the seasonal outlook to head of institutions such the director of the extension services of the Minister of Agriculture (MOA) and the director of the development services at the Uganda Coffee Development Agency (UCDA). Secondly, following the MOA branch, the forecast is delivered to the head of the Production Office at a district level. Within the Production Office, the head of the Natural Resource department convenes a meeting with agriculture officers and major stakeholders of key economic sectors of each sub-county to discuss the forecasts with the aim to design a strategy plan for the territory. Once the meeting has been concluded, agriculture officers spread the forecast to all parishes belonging to the sub-county they work for. It is at this level where the coffee cooperatives established by HRNS (Depot Committees (DC)) typically operate. This means that, members of the board of the DC, such as the ones I have interviewed, should be the ones, among other stakeholders, who receive and discuss seasonal forecasts with the agriculture officer. Following the HRNS organizations' structure, forecast should be thus finally available at the Producer Organizations level (PO) that averagely gathers village groups of 20-30 farmers.

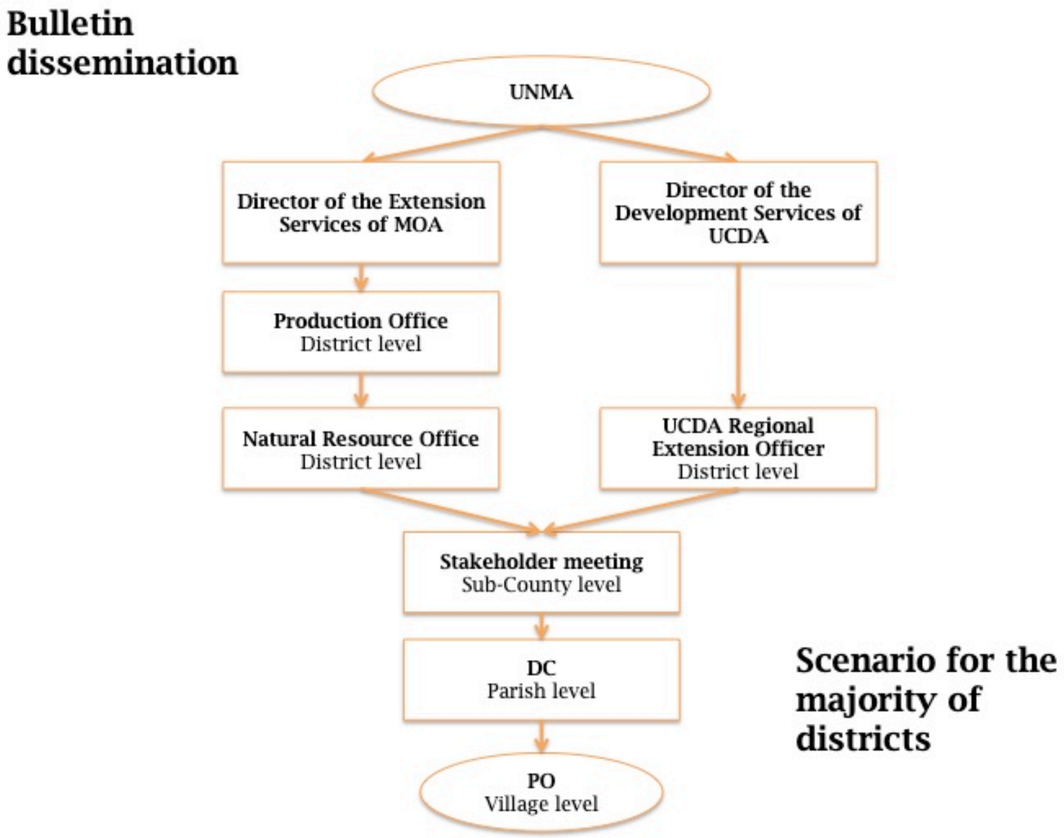

Figure 17 – Flow chart of the dissemination of a Seasonal outlook in the majority of Uganda districts.

This long and complicated chain does not favorite a smoothly dissemination of weather and climate information over the territory. Thus, to reduce the potential inefficiencies stemming from this system, UNMA as a trial project has recently started delivering seasonal outlooks to the Natural Resource Offices of 22-target district, Luwero included. However, as describes in the final part of the third chapter, there are other issues that may still obstruct the efficiency of this service.

3. The district of Luwero

Within the opening part of this chapter, after a brief description of the district and the type of coffee this area produces, the paper wants to describe the historic climate pattern and change in the Luwero district by mainly using farmers' descriptions. The purpose is to outline on one hand the very different way farmers experience and read the weather, fundamental element to suppose the realization of a cultural bridge. On the other, to highlight their incredible ability to observe changes in the environment that surrounds them, a skill that may be valuable for countries where observational data is missing. The second section of this chapter describes the recent pronounced variability farmers have been exposed. Although incredibly important, understanding whether these changes are due to internal natural variability or climate change is not the objective of this section. Instead, the aim is to mark out the farmers' openness of receiving climate and weather forecast as their sign technique seem to have become less reliable in the past years. The final part of the second section describes the farmers' perception of the service provided. The third and final section of this chapter describes the way seasonal outlooks are disseminated in Luwero with the aim to increase the intelligibility of the weather forecast.

3.1 Coffee & Climate: the Indigenous knowledge

The district of Luwero lies in the central region of Uganda, latitude 0.5° North and 32.3° East. In Luwero there are ten subcounties and the interview have been taken place in Katikamu and Butuntumula (Figure 18), where the plateau altitude is about 1,000 meters. After have covered about 70km or two hours driving north of Kampala, an incredible landscape welcomes Mr. Komakech, Mr. Geoffrey – the HRNS driver – and I at the district. Almost similar across the entire itinerary, the scenery consists of a series of blood-red flat-topped hills interrupted in-between by valleys (Figure 19). And the contrast with the green vibrant vegetation is very unique, particularly with the color that characterized the leaves of coffee tree.

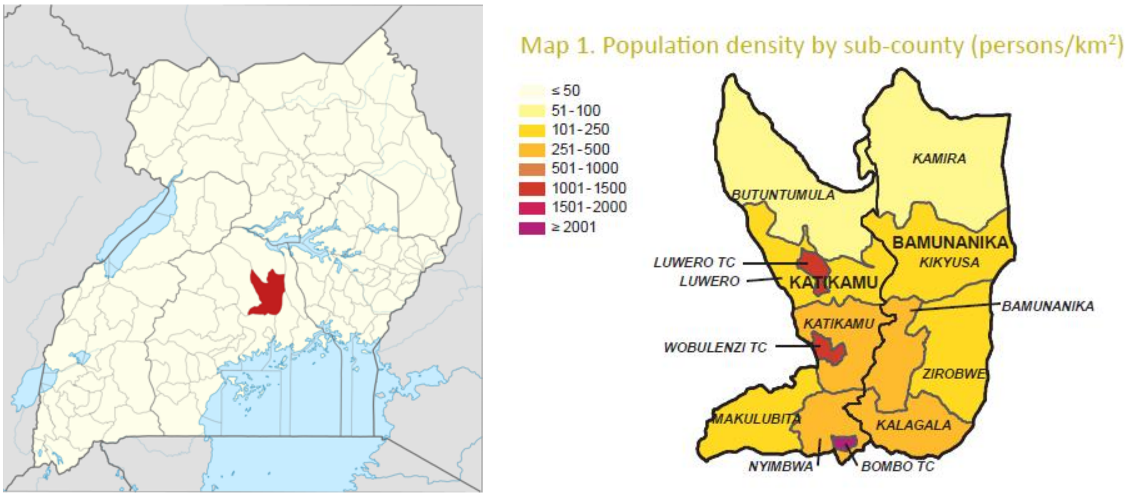

Figure 18 –Left: Luwero district. Source: Wikipedia. Right: Luwero district and its sub-counties. Source: UBS

Figure 19 – On the way to Luwero District. Picture of Filippo Radice

In Luwero it is only produced the *Coffea canephora,* better known as Robusta coffee. According to a collaborative work led by the Uganda Coffee Development Authority (UCDA 2011[13]), Coffea canephora is a robust shrub or small tree that may reach 10 meters in height, but with a shallow root system (Figure 20, 21). Potentially, Robusta can reach very high yields that may range between 2300 – 4000 kg green beans per hectare. To do so, this plant would need, among other variables, an yearly average temperature an rainfall in the range of respectively 24-30°C and 2000-3000mm. If the average temperature of Luwero is within the Robusta optimal range, the total amount of rain that distinguishes this region is far below it. The FEWS NET 10-day rainfall time series indicates a yearly average total amount of about 1,200mm for the period June 1995 – May 2019. Yet, according to HRNS the average coffee yield in this area is 600 -1200 kg green beans per hectare – way less than its optimum yield – it is mainly due to the few level of practices farmers generally implement. The Annex 2 provides the reader with more details on how –everything else being equal -uptaking specific agronomic practices may be key to boost higher yields and farmers' profitability.

Figure 20 - Robusta tree planted in 1947. Mr. Bazannyanengo Alooni Kiyaga farm. Katikamu sub-county. Picture of Filippo Radice

[13] https://coffeestrategies.com/wp-content/uploads/2015/04/compiled-standards-distribute1.1.pdf

Figure 21 - Young Robusta tree. Mr. Bazannyanengo Alooni Kiyaga farm. Katikamu sub-county. Picture of Filippo Radice

When I asked farmers to describe me the climate of the region, all their stories started with the rainfall pattern. In this area of the planet, rainfall means survival. The rain is vital for farmers' activities, as irrigation systems do not simply exist. Sometimes you can find at the bottom of some trees upside down plastic bottle spilling greedily drops of water, but agriculture is mainly rainfed (figure 22).

Figure 22 - Rudimentary irrigation system. Mr. Bazannyanengo Alooni Kiyaga farm. Katikamu sub-county. Picture of Filippo Radice

The production of staple and cash crops entirely depend upon rain. It shouldn't surprise then, how meticulous and accurate memories they have in terms of historic rainfall distribution. They all have started the interview by describing the bimodal rainfall pattern of the region. According to their memories, all have agreed that the first and most abundant rainy season or *Toggo,* starting at the end of February, beginning of March and ends at the end of May, beginning of June. The second one or *Ddumbi* begins for two farmers in the middle, late part of August and end in November, while for the others its onset is in September and its cease generally occurs at the beginning of December.

While interview was going further, more finer pictures farmers were providing. In terms of rainfall pattern, they have all agreed on saying that it starts with a very small amount and then increasing by reaching its peak in the middle of the each season and start decreasing afterward. End of April and beginning of May has been identified as the peak rainfall period for Toggo. Even though they didn't explicitly cite the peak of the second season they have all agreed on saying that the "shape" of the distribution is similar to Toggo but with less amount of rain. Only one farmer said that the amount of rain is almost equal. This means that according to their witnesses the peak of rainfall may be potentially in October. December January and February and June, July and August have been identified respectively as the first or second dry seasons. In Luganda there is no distinction and thus both seasons are called Omusana. As we can see in the following graph, by using a ten-days rainfall time-series from FEWSNET dataset there is the chance to picture farmers' descriptions.

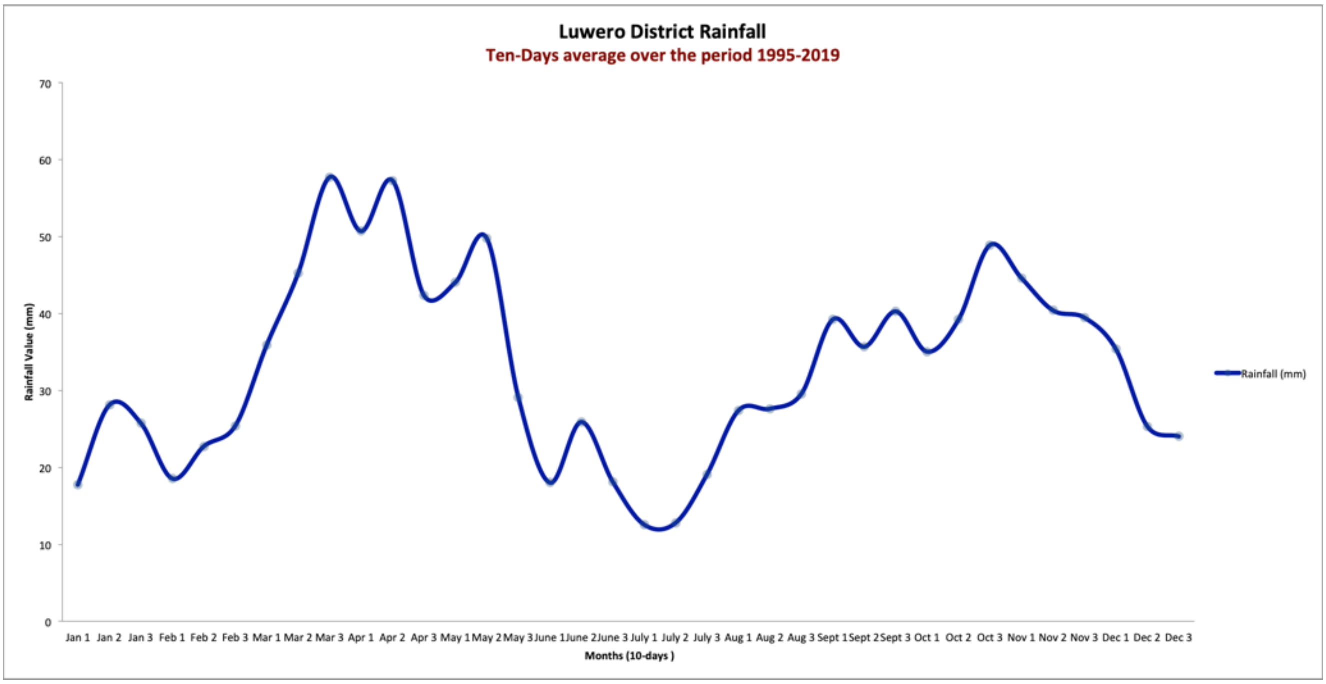

Figure 23 - Luwero district rainfall pattern period 1995-2019. Source: data from FEWSNET

Although there are some discrepancies in the identification of the rainfall peak, the pattern of the two seasons is quite accurate by suggesting that smallholders' do have a very attentive capability of observing weather dynamics. Indeed, if we consider that farmers' knowledge is pass throughout generation with verbal tradition in an area where the rain never fully ceases. A hypothetical explanation of this accuracy may lie on the fact that this rainfall pattern is vital for the coffee development. Indeed, more precise information was provided when farmers were asked to describe the two coffee seasons, Mbirabira and Eyomwaka whose harvest period generally occur respectively around June and December.

According to farmers' stories to guarantee both higher coffee yields and quality, the distribution of rain seems even more important than the yearly total amount. I presume that this aspect may explain why farmer's climate narrations were becoming more accurate as soon as they were describing Mbirabira and Eyomwaka. Farmers have all characterized these two seasons by emphasizing two events, the flowering and the harvest and between them it typically takes from 10 to 11 months (UCDA, 2011). The flowering always occurs during the onset of the rain, whilst the harvest during the dry season. Although the same tree can hold both fruits, the flower of the "fly coffee", a product of Mbirabira, typically blossom in September and thus harvested in June. Instead, the flower of the "main coffee", a product of Eyomwaka, generally bloom between February, March and therefore harvested between November and December.

As extensively explained by all farmers, the rain must come in a little amount during the flowering event and aftermath increasing to guarantee fruit formation. If the rainy season is characterized by a different pattern, either intense rainfall at the onset or a prolonged dry spell afterwards the flowering, flowers may decay, rot without producing any fruits. Farmers' scrupulous attention to the first rainy season may be due to the fact that the majority of their income entirely depends upon the "main coffee" produced in Eyomwaka. And according to all farmers, the quality and amount of it principally depends upon Toggo, the first rain.

Figure 24 - Left: Main coffee. Right: Fly coffee. On the same plant it is common to find fruits for both season, mbirabira and eyomwaka. Mr. Bazannyanengo Alooni Kiyaga farm. Katikamu sub-county. Picture of Filippo Radice

Farmers' seasonal forecasting system is very different from what has been described in the second chapter. The way they detect the beginning and the cease of a particular season makes them accurate observers. Farmers' deep climate knowledge has been established by decades of sensorial observations of any kind. Farmers' ability to detect a seasonal change is a totally body experience, tactile, auditive and visual. The most obvious sign – in Luganda *Obubonero*[14] – almost all farmers have given as a first answer for the onset of the rainy season is the cloud formation. Yet, their visual wisdom goes way beyond the observation of the sky. They are very attentive to all changes in the environment. For instance, *Milicia Excelsa (*figure 25*)* is a large tree that may reach up to 30-50 meters, generally employed in soil conservation and as an excellent shade tree. But farmers are using its leaves for both mulching and "weather forecasting". Indeed, when new leaves appear, the onset of both rainy seasons should begin. Although the biology of this plant changes depending on the area, the worldagroforestry[15] reports that in western Kenya new leaves appear from October to December and in January and February.

Figure 25 –On the back of the picture there is the Milicia Excelsa. Mrs. Nalugooti Gertrude Musoke farm. Picture of Filippo Radice

[15] http://www.worldagroforestry.org/treedb/AFTPDFS/Milicia_excelsa.PDF

Another type of tree generally used as firewood, timber or charcoal that farmers even observe for planning their activities is the *Albizia Coriaria* with the same mechanism as described above. In addition to that, there are even particular insects that may suggest farmers that the rainy season is about to begin. The *Enkoloto* is highly visible before the onset of the rain as it is the time when it can easily store food. Although I could not find details on it – as the name provided is in Luganda – another farmer brought up as example a more common insect that manifest the same behavior: the black ant.

Farmers' connection with nature is absolutely unique and thus they do not trust only their eyes to start programming their seasonal calendar. There is too much to lose. Before making any decision, they wait other signals as the chirping of particular birds such as *Tutuma*, *Enganga* or the *Crested Crane (*figure 26*),* the latter a symbol of the country set in the Uganda flag.

Figure 26 – Crested Crane. An important sign for the onset of the rainy season and symbol of the country. Source: https://greattrekkers.com/56-reasons-love-uganda/

As already extensively outlined, farmers picture the differences between seasons by using their whole-body feelings. By combining farmers' words, a typical Omusana day they often experience should be as follow: very cold morning with a reddish sun on the horizon and some mist on the ground. And as the sun rises throughout the day so do the temperatures by leaving the fog as a first distant morning memory and cloudless sky. Lastly, nights have been described extremely cold compare to the warmer's one brought by Toggo and Ddumbi.

However, they have all detected a change in the climate that they have never experienced before. And this ability to predict a change in the season seems to be partially vanished. There is a very high agreement among the farmers I have interviewed that nowadays all these signs are not always reflecting the climate conditions they would expect.

3.2 Internal climate variability and change – a need of external sources of weather and climate information

The climate of the central part of Uganda, as well as other area, has always been highly variable. For instance, as reported by the following figure (Nsubuga, 2014), the central region of Uganda has been experiencing since 1940s period of yearly total amount of rainfall above and below the average.

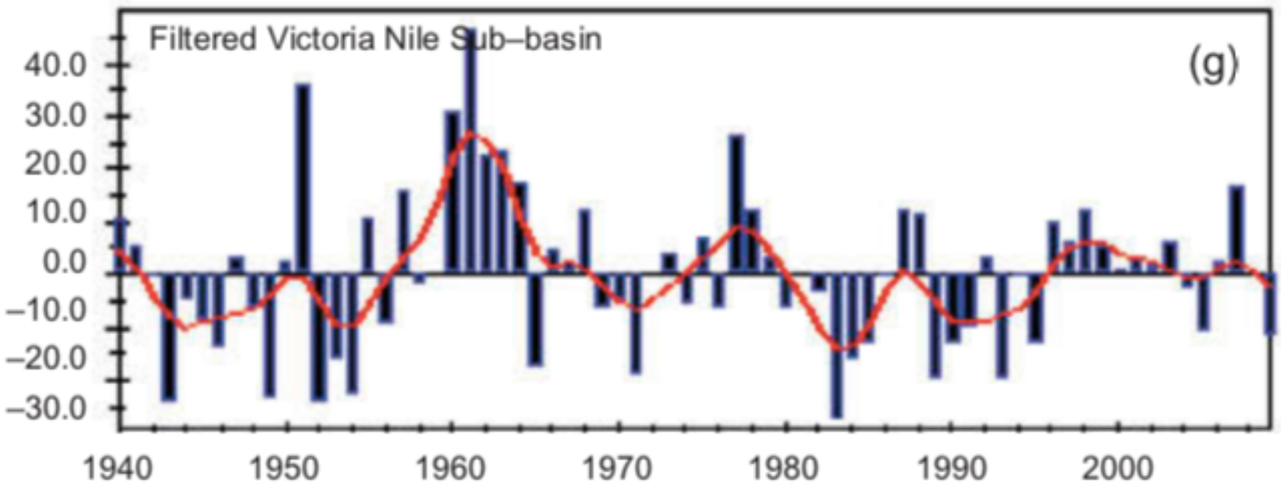

Figure 27 - Rainfall variability in Nile sub-basin where Luwero district is located. Source: Nsubuga, 2014

Yet, what we cannot see in the above figure is the potential change of the intra-seasonal rainfall pattern that according to the IPCC climate-scenario – described in the first chapter – it may be exacerbated by climate change in the next 30 years all over Uganda.
As stated during the interviews as well as reported by the HRNS staff, the central region has lately recorded prolonged dry spell during the rainy season.
And the changes in the climate condition farmers have been recently exposed to are a dramatic threat for their economy.

Farmers have named this period as "***Enkyuka Kyuka mumbera Yobudde***", where "**Enkyuka Kyuka**" "**mumbera**" and "**Yobudde**" mean respectively **variability**, **condition** and **climate**. The main change they have detected is in the intra-seasonal rainfall pattern. It seems less "organized" than before. Farmers reported that in the past five or six years they have been receiving more rain during the sunshine season and less rain during Toggo and Ddumbi by thus reducing the production and quality of their harvest. For instance, less or mal distributed rain in Toggo and Ddumbi may lead the flower to fade by thus reducing yields. Moreover, aftermath the harvest and before the sale, coffee needs to be dry out. This operation happens under the sun In Uganda, as farmers do not have financial resources for purchasing advance technologies such as a pyrolysis plant. Therefore, more rain in Omusana may increase the likelihood of mold development within coffee beans by thus reducing the quality of it. However, as we can see from the following graphs, the rainfall pattern across the period 1995-2019 is very noisy. By comparing the past four years of rainfall relative to the average of the period June 1995 – December 2015 (Figure 28, 29, 30, 31), some changes can be observed particularly during the first rainy seasons, but it is hard to say if these changes are more pronounced than before.

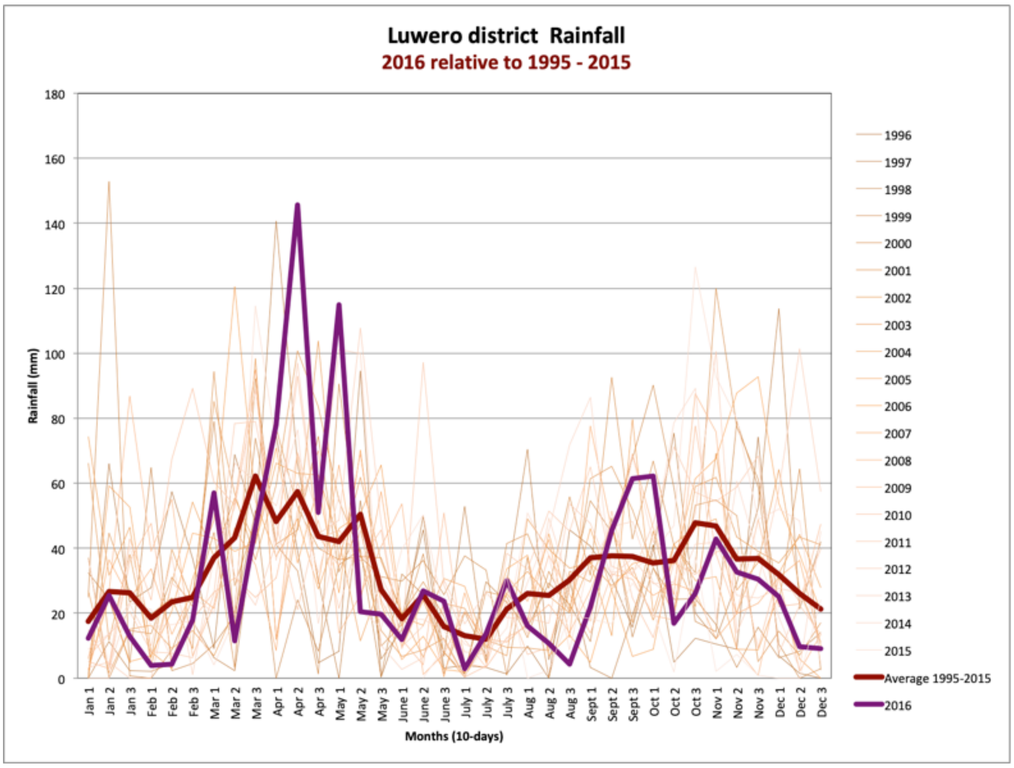

Figure 28 – 2016 rainfall distribution relative to 1995-2015. Source: data FEWS NET

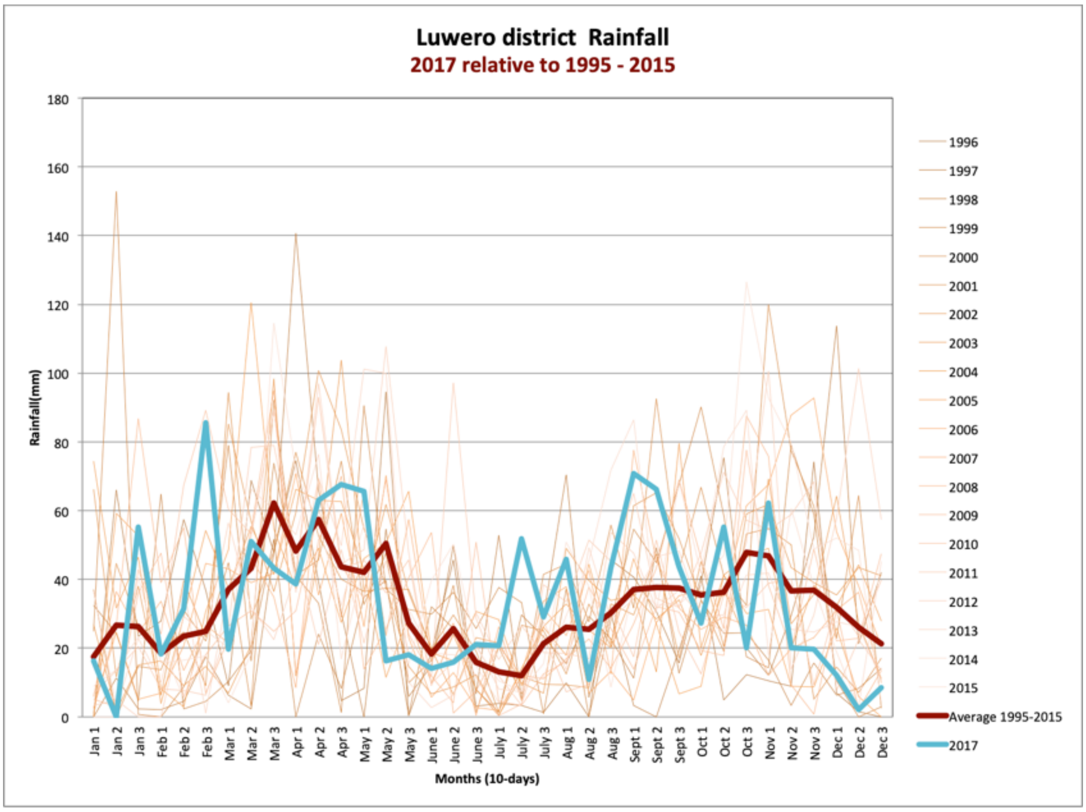

Figure 29 -2017 rainfall distribution relative to 1995-2015. Source: data FEWS NET

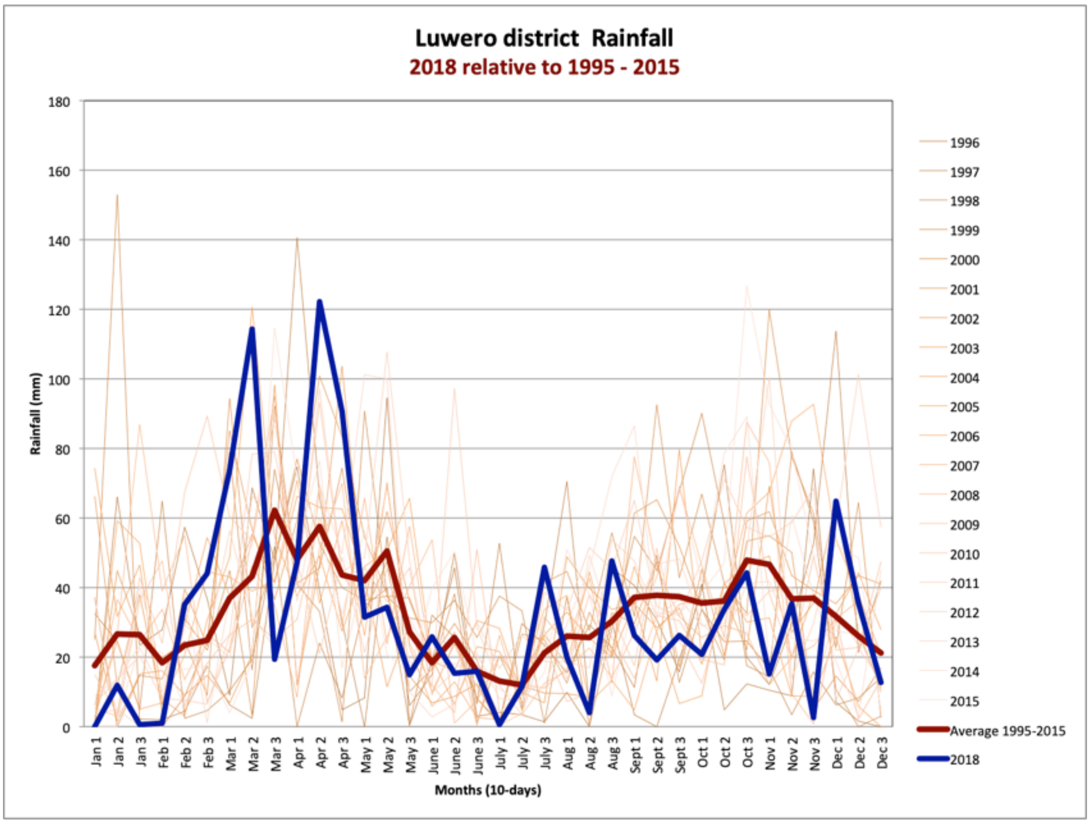

Figure 30 -2018 rainfall distribution relative to 1995-2015. Source: data FEWS NET

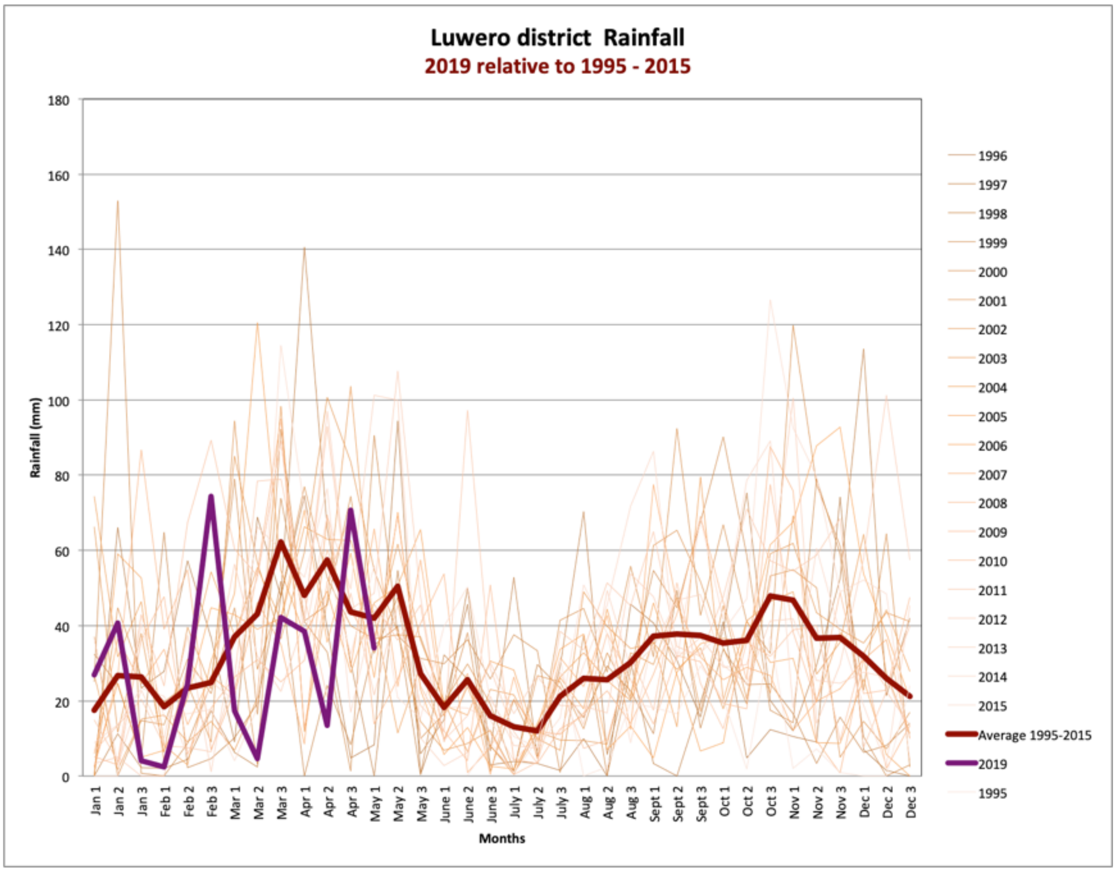

Figure 31 - 2019 rainfall distribution relative to 1995-2015. Source: data FEWS NET

Nonetheless, once again detecting potential trends is not the scope of this study. To highlight their openness to external weather forecast, during the interviews, farmers detailed the climate variability with few other examples.
Temperatures seem have increased throughout the year. One farmer ironically has declared that they have started dressing lighter because of the temperature increase. Pests and diseases seem to be more common, even though it is not clear in which season. For two of the farmers pests and diseases are more abundant during the dry and rainy seasons respectively, whilst the others two have reported the exact opposite pattern. The nowadays-major concern reported is the *black coffee twig borer*. This tiny beetle nest inside of coffee tree branches, obstructing the water flow by thus making drupes to abort (figure 32, 33). Another important reported issue by farmers is related to the biology of the coffee plant; in their past 30-40 years of farming activities, they have never experienced flowering and harvesting episode in April (figure 34, 35).

Figure 32 - black coffee twig borer infestation. beetles coming out from a broken branch. Mr. Ssekandi Daniel Godfrey farm. Picture of Filippo Radice

Figure 33 - black coffee twig borer infestation. Mr.Ssekandi Daniel Godfrey farm. Picture of Filippo Radice

Figure 34- Left: flowering in May. Right: ripe coffee ready to be harvested. . Mr.Ssekandi Daniel Godfrey farm. Picture of Filippo Radice

Figure 35 – atypical April harvest. Mr. Bazannyanengo Alooni Kiyaga farm. Katikamu sub-county. Picture of Filippo Radice

Farmers believe that the more intense winds, the more frequent hailstorms, the increase in temperatures and spread in pests and diseases and the weird pattern of rainfall are all due to human activities: deforestation, wetland degradation and even emissions have been identified as the major drivers of this climate crisis. Although the explanations of this climate variability may be not completely correct, these declarations have outlined that there could even be an openness to reduce their environmental impact, as awareness is always the first step for a change. Accurate climate and weather forecast may let them use more efficiently both fertilizers and pesticides by thus increasing their profitability while reducing their carbon footprint. As previously mentioned, the conspicuous inter-annual and inter-seasonal climate variability have convinced farmers to be willing to integrate their climate knowledge with other sources of information such as radio. Unfortunately, they all have stated that there is a spread tendency not to trust weather forecast due to unreliability and sometimes lack of clarity, understandability of the information. For instance, on the *March to May 2019 Seasonal Rainfall* outlook released on the 22nd of February 2019, was forecasted a near normal with a tendency to above normal rainfall over the country (figure 36). More precisely Luwero should have been experienced "with high chances near normal rainfall with slight tendency to above normal". The onset of rainfall was expected around early to mid-March.

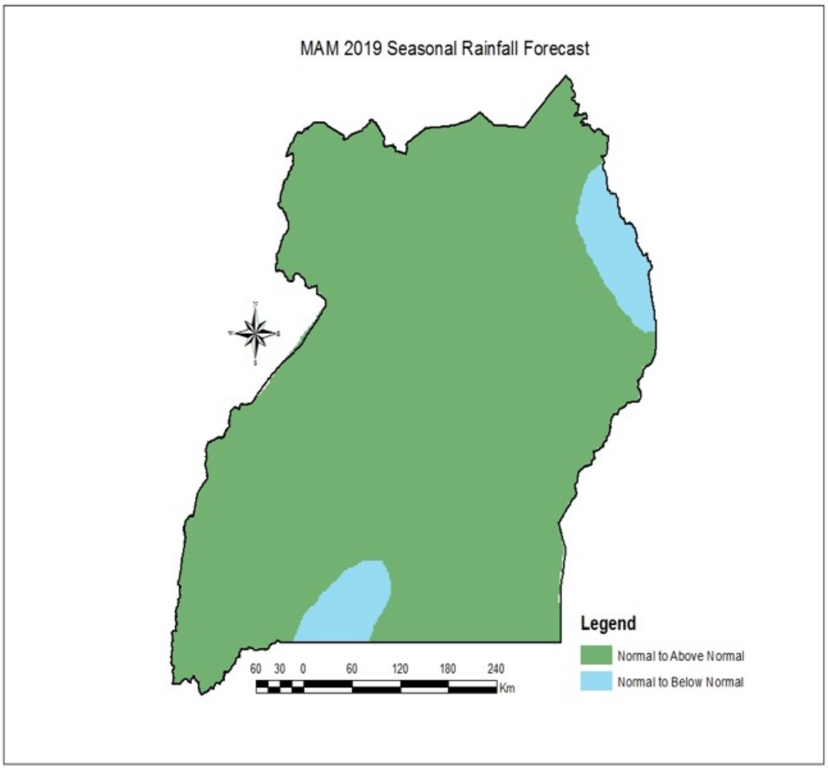

Figure 36 – Map of the MAM 2019 Seasonal Rainfall Forecast. Source: UNMA

However, as pictured by the figure 31, the amount of rain has remained below the average till the end of April, and again below the average in the first ten days of May. Mr. Komakech has declared that Luwero has finally recorded constant rain starting from the middle of May, two months later what have been stated in the seasonal outlook. Furthermore, on the 21st of May 2019, FEWS NET has released an emergency assistance alert for deterioration in food security conditions across the Horn of Africa. The alert declared that rainfall during the first period of the long rainy season has been on average less than 50 percent all over the Horn of Africa, whilst less than 80 percent on average across Uganda[16].

Farmers were ready to expect heavy rainfall already in the middle-end of March. Mrs. Nalugooti Gertrude Musoke has declared that the radio announced possible flooding events in Luwero. Instead, the prolonged dry spell has lasted till the middle of May, by burning down crops that have been sown in March, as farmers though that Toggo was started.

Mr. Bazannyanengo Alooni Kiyaga, another farmer I have interviewed, has actually received an update of the seasonal outlook. The alert stated that the March rain would have been a false onset of the season. During a DC meeting he tried to alert other farmers and yet most of them have nonetheless decided to sow by consequently losing their crops. Even if he did not specify from which type of sources he has receive the update, it is important to outline that Mr. Alooni was the only one with a TV and a smartphone.

Although it is just a hypothesis, Mr. Komakech and I had the feeling that all farmers have implicitly marked out an important factor: if the message they receive is not reliable, they would be still keen to look for other source of information. But they would stop listening the messenger of the wrong message. This factor may help us to understand the reason why a discussion on weather forecast between agriculture extension officers and farmers is not may be happening as much as the government thinks. Farmers would be willing to discuss weather forecast through the official meetings organized by UNMA and yet they – as well as the whole personnel of HRNS – were not aware of the program implemented by the government.

[16] http://fews.net/east-africa/alert/may-21-2019

3.3 Weather and climate services in Luwero, a government and farmers perspective

To reduce the potential inefficiencies stemming from the dissemination system of seasonal outlooks implemented in Uganda, UNMA in partnership with Africa Climate Resilience Alliance consortium (ACCRA), has implemented in 22 *targeted-districts* the WISER project whose aim is to distribute forecats among farmers more efficiently[17]. Luwero is among these districts that have been selected because of their persistent exposure to weather stress and their key economic value in terms of agriculture productivity. As we can see from figure 37, this project drastically decreases the number of passages to reach farmers. Figure 38 lists the different interviewed stakeholders in Luwero.

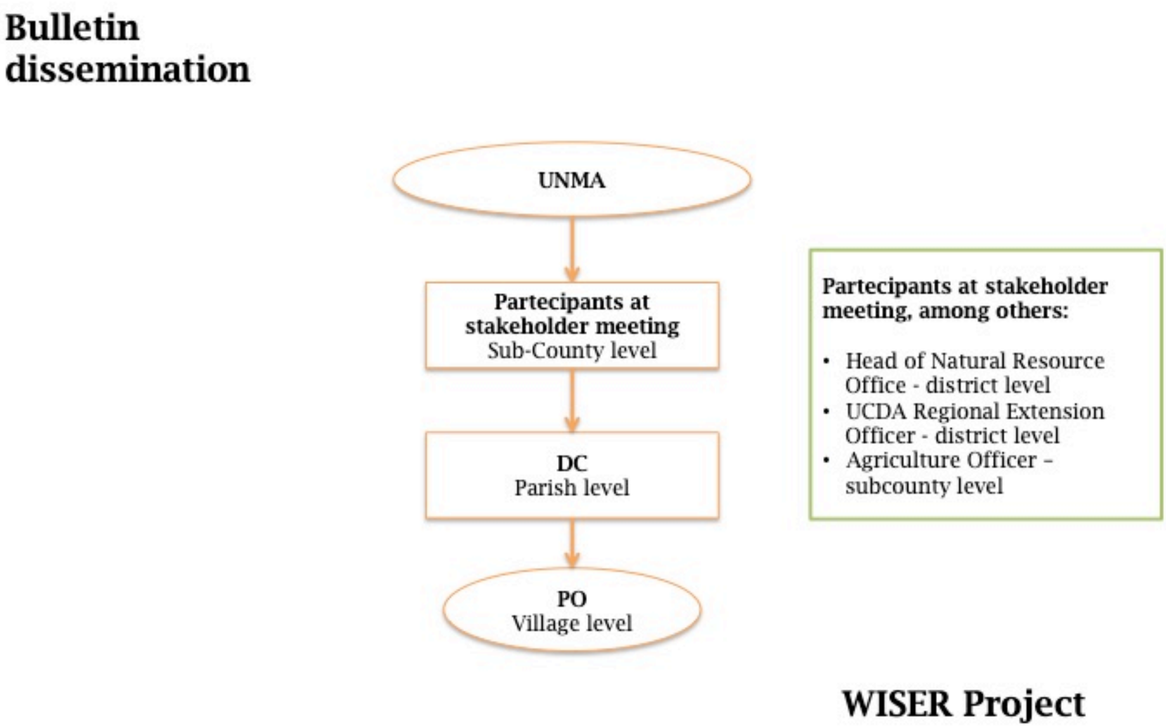

Figure 37 - Flow Chart of the WISER Project.

[17] https://www.metoffice.gov.uk/about-us/what/working-with-other-organisations/international/projects/wiser/uganda

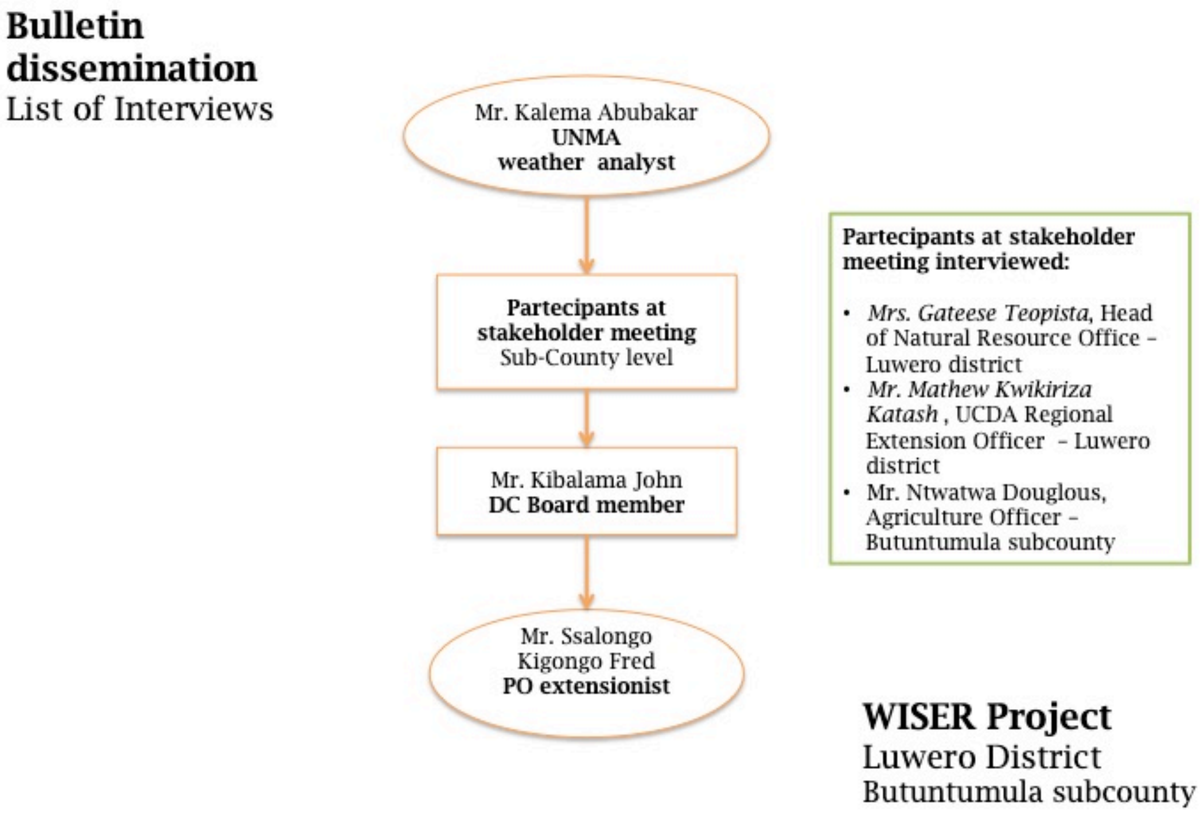

Figure 38 - List of interviews performed in Luwero.

While discussing with the different government agencies, Mr. Komakech and I had both the feeling that the program was already fully and properly implemented.
For instance, Mrs. Gateese Teopista, head of the Natural Resource department of Luwero, explained us that they have been regularly organizing the stakeholder meeting for the seasonal outlook update every month. Moreover, Mathew Kwikiriza Katash the UCDA Luwero extension officer, and Mr. Ntwatwa Douglous, the agriculture officer of the Butuntumula subcounty, both confirmed us the same fact. Mr. Douglous has stated to have reached so far about three thousand farmers out of 5,249 working in Butuntumula. On the other hand, no one from the personnel of HRNS, one of the biggest Luwero coffee stakeholder that represents in the subcounty of Butuntumula and in the subcounty of Katikamu respectively 12% and 11% of the total amount of smallholders, has ever heard about this project.
Mr. Bazannyanengo Alooni Kiyaga – member of the board a DC working in the Katikamu sub-county – as well as the other farmers I have interviewed – has never had the chance to meet an agriculture officer. More importantly, all famers were not even aware of this program.

A question that has risen spontaneously at the moment of the interviews has been why an organization as important as HRNS was not aware of the weather and climate forecast dissemination program implemented by the government. The lack of coordination among agencies, explained by the principal-agent theory, may partially explain why HRNS has never been involved in the stakeholder meeting. Yet, there could be another reason, which may obstruct the distribution of the weather and climate forecast from the Parish to Village level: parish leaders and agriculture officer may fear to lose trust and credibility among farmers.

For instance, the former Butuntumula agriculture officer has been substituted with Mr. Ntwatwa Douglous, as farmers did not want to meet him anymore after they have been provided with unreliable weather information.

This final episode opens an important issue: farmers do not know the meaning of a weather forecast. Since even the most advanced weather forecast contain bias, creating a participatory dialogue with farmers to explain them what a forecast is, seems crucial. Without understanding what a weather forecast really means, It is likely that farmers wouldn't be able to uptake any other source of information.

4. Bridging the gap between farmers and forecasters.

Climate natural variability and change are both exacerbating a reality, which is already insecure, unstable, fragile. From this dense two-weeks journey I have learned that working in building resilience requires a very high and delicate emotional intelligence, which has let an organization such as HRNS primarily gaining an incredible amount of trust from farmers and thus being in a position to deeply understand their needs and help smallholders to fulfill them. For instance, gender inequality is an important issue the Foundation is dealing with. In the majority of time, women are taking care of everything, from farming practices to housewife activities and yet men decide where to invest their profit, and often times not in the most honorable manner. To prescribe the potential recipe for this deep social wound, HRNS firstly wanted to discover smallholders' talent. It seems they have found incredible actors. Thus, to increase awareness on this important issue, the foundation organizes drama where volunteers husband and wife show to the rest of the community the benefits they could gain if they start making decision together and compare it with a background scenario where the husband spends all money in gambling and alcohol.

There are other important topics HRNS is working on to enhance business resilience of farmers. The level of literacy is quite low amid smallholders and most of the time they do not even know how to keep track of their yearly costs and benefits. Lack of equity and organizational structure lead single smallholder not to have access to formal financial services. Thus, farmers are forced to borrow finances from the middleman, a usurer that lends money with an interest rate of 20-50%. At the same time the middleman bonds the smallholder to sell him coffee for a very low price: 0.96 USD/kg, when the net price paid by a Depot Committee is 18.7% more or 1.14 USD/kg.

The topic of trust is essential in this analysis. Once farmers' trust is lost, it is hard to earn it back. For instance, the reason why HRNS has named the large organizations as "Depot Committee" and not "cooperatives", is because farmers would have not joined them as the latter have taken advantages of them in 1990s. The former Butuntumula agriculture extensionist officer, lost his job as farmers refused to meet him. The forecasts provided to farmers were not always reliable. The *March to May 2019 Seasonal Rainfall* outlook, released on the 22nd of February 2019, was forecasting a near normal with a tendency to above normal rainfall In

Luwero. Yet, the amount of rain has remained below the average till the middle of May, a situation that has convinced FEWS NET releasing an emergency assistance alert for deterioration in food security conditions across the Horn of Africa. The alert declared that rainfall during the first period of the long rainy season, has been less than 80 percent than the average across Uganda. Farmers have literally seen their crops being dried up by this prolonged dry spell, and thus shading their future profits. When the consequences of a wrong message are so severe, losing trust in the messenger is almost inevitable.

The feeling Mr. Komakech and I had during interviews, is that farmers are confused on the significance of a forecast. Since they are receiving different information throughout the season, they may think that, on the other side of the radio, there is someone who is betting on future weather conditions. Mrs. Nalugooti Gertrude Musoke has declared that the radio announced possible flooding events in Luwero, while Mr. Bazannyanengo Alooni Kiyaga, another farmer I have interviewed, has actually received an update of the seasonal outlook that it was announcing the dry spell. Mr. Alooni tried to advice other farmers not to sow but few of them have followed his suggestions.

However, they still have all expressed openness to external source of information. They would be willing to participate in meeting to discuss about forecasts and make formal decision out of it. Someone has even suggested a slot at the moment of the interviews. They would prefer meeting once per month, when the producer organizations' meeting already occurred. During these workshops farmers generally discuss about the agronomic practices established under the *Feed the Future Alliance for Resilient Coffee* projects with the aim to identify potential barriers and increase the efficiency of these practices.

Given the high level of trust placed in HRNS, farmers have thus indicated the foundation as the potential new messenger they would be willing to listen. And this openness is a very positive factor. Since forecasts always contain bias, regardless the different inefficiencies UNMA CWS may have, creating a cross-cultural participatory dialogue between forecasters and farmers seems crucial. Farmers have always had their own way to read the weather and detect a seasonal change. In the conventional way of thinking, it is assumed that climate scientists are the active players in producing weather forecasting, whilst local farmers have a passive role as "recipients of forecast" (Roncoli, 2017). Instead farmers should be seen as users as well as active players in the production and dissemination of weather and climate information. As we have seen in the third chapter, farmers are very attentive climate observers and they may be an important source of information for a country such as Uganda characterized by a lack of observational data. This cross-cultural participatory dialogue may be beneficial for both players, forecasters and farmers.

HRNS may be in the position to favorite this dialogue as it does have gained a high level of trust from both Institutions and farmers. For instance, while Mr. Komakech and I were interviewing the officers from the different governmental agencies, they were all asking HRNS to help them improve the Uganda CWS. Mr. Kalema Abubakar, weather analyst at UNMA, asked Mr. Komakech to help him to increase the densification of rain gauges in Luwero, with the aim to gather more observational data and thus improving weather forecast. Mrs. Gateese Teopista, head of the Luwero district Natural Resources department, has formally invited HRNS in participating in the monthly stakeholder meeting, to discuss forecasts before its disseminations. HRNS may be in a position to organize such a dialogue between farmers and forecasters with the aim to improve communication, to enhance trust and credibility amid different actors by thus bridging the gap between farmers and governmental climate services. As already mentioned, optimal climate and weather services relates to the ability to produce reliable seasonal outlook and to disseminate it in a timely and understandable manner. Therefore, to improve the Uganda CWS, the communication gap must be first filled in.

Annex 1 – Luwero district local farmer Interview

Interview structure

The interview has been divided up into three different sections: the first one asks farmers to describe the historic climate pattern and change of the Luwero district. I was interested to understand local farmer's ability to detect climate natural variability and change through their climate knowledge, as well as their way of communicating climate pattern. The aim of the second section is to understand coffee farmers needs. Indeed, understanding their demand of weather and climate forecasting product relative to their seasonal farming activities. The third and final section is dedicated in identifying the type of information climate forecasters and sector expert are both providing coffee farmers with and how.

<u>Order of farmers interview:</u>

10th of April 2019

1. Nalugooti Gertrude Musoke. 32 years old. (Farmer/demo host) Katikamu subcounty, DC extensionist
2. Ssekandi Daniel Godfrey 50 years old (Farmer/demo host) Katikamu subcounty, DC extensionist

11th of April 2019

3. Bazannyanengo Alooni Kiyaga 63 years old (Farmer). Katikamu subcounty, The Chair of the DC committee
4. Ssalongo Kigongo Fred. 53 years old (Farmer/demo host). Butuntumula subcounty

Interviews

1. Introduction

- Name and surname
- Members of farm/family: gender, age
- Size of the farm
- Number of years s/he has been producing coffee

2. Section 1: Local climate knowledge[18].

Historical climate pattern (mumbera Yobudde) – understanding the baseline and its relevance for coffee growth:

a. Could you describe me the two rainy seasons, **Ekire Ekisooka** (toggo) vs. **Ekire EkyoKubiri** (ddumbi) Which are the main differences between these two rainy seasons?
b. What season is the most important for coffee? Why?
c. Could you describe me the dry season, **Omusana (**literally sunshine) or **Seasoni eyomusana**?
d. Is the dry season important for coffee? Why?
e. Could you describe me the two coffee seasons, **mbirabira** vs. **eyomwaka**?

[18] This second section is based on the following paper: Ben Orlove, Carla Roncoli, Merit Kabugo. "*Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system*". November 2007. Springer

Their ability to forecast, predict weather and climate internal variability

a. Which major "Signs" **Obubonero** announce the onset and the end of the rainy season **(Seasoni eyenkuba)** and the beginning and end of the dry season (**Seasoni eyomusana)**?[19]
b. Could you provide me with few examples of "***Obubonero***" you would use to plan your daily, weekly activities?
c. Could you provide me with few examples of "***Obubonero***" you would use to plan your seasonal activities?

Their ability to detect Climate Variability or "Enkyuka Kyuka mumbera Yobudde"?

a. Which ***Obubonero*** are making you think that the climate **obudde**[20] now is different than before? Which ***Obubonero*** would you use to describe **Enkyuka Kyuka mumbera Yobudde**[21] (Pronounce: Enciuka ciuka mumbera iòbudde) ?
    i. NOTE: it seems they do not talk about climate change but climate variability.
b. What do you think is the cause of the climate variability you have recently noticed?
   Why is **Enkyuka Kyuka mumbera Yobudde** happening?

[19] In the same paper the following signs have been detected: increase in nighttime temperatures, shifts in the direction of prevailing winds, phases of the moon, flowering of the tree and arrival of migratory birds such as Abyssinian hornibill. It apparently recall the Luganda word ggulu = "heaven"→ "ggulu mpa enkuba" = "Heaven, send rain".

[21] Enkyuka Kyuka = Variability; mumbera=condition; Yobudde=climate. Obudde if there is no words before it

3. Section 2: Farmers Needs

Seasoni eyomusana (dry season) and Seasoni eyenkuba[22] (rainy season) forecasting:

a. *What* are the most important *activities* you should plan to guarantee high coffee yield and quality every season, **Seasoni eyomusana and Seasoni eyenkuba**? *Why*?
b. *When* the *activities* you listed should be implemented? In which part of the year? *Why*?
c. *What* are the most important *seasonal information* you would need to be able to efficiently implement the list of activities described above? *Why*?
d. *When* the *seasonal information* you listed should be provided? In which part of the year? *Why*?

Buli Lunaku (every day) and Buli Sabiti (every week) forecasting:

e. *What* are the most important activities you need to do **Buli Lunaku and Buli Sabiti** during the rainy seasons **Seasoni eyenkuba**?
    i. What are the most important **obudde** Information you need to receive **Buli Lunaku and Buli Sabiti** to implement these activities ? Why?
f. *What* are the most important activities you need to do **Buli Lunaku and Buli Sabiti** during the dry season **Seasoni eyomusana**?
    i. What are the most important **obudde** Information you need to receive **Buli Lunaku and Buli Sabiti** to implement these activities ? Why?

[22] A way to describe the Rain in general

4. Section 3: "Actual weather and climate information provided" [23].

Seasonal forecasting:

a. What is source of information (UNMA, local government, extension officers, NGOs, traditional forecaster and indigenous knowledge..) you use the most? *Why?*
b. How do you mainly receive climate forecasting? Rural Radio, SMS, Voice recorded messages, Agro-met bulletin, group meetings, external officer?
    i. Among these "communication channel" which one do you think is the most effective one? Why?
c. Is it provided in *time*?
d. Is it (averagely) *accurate*? *Why* yes/no?
e. Do you use it at all? *Why* yes/no?
f. Do the major sources provide you with advices? If so, may you give me some example? Are they useful in terms of decision-making? Why yes/not?

[23] Leading questions found within the following paper: Vaughan C., Hansen J., Roudier P., Watkiss P., Carr E. December 2017. *Evaluating agricultural weather and climate Services in Africa: Evidence, methods and learning agenda.* A learning Agenda on Climate Information Services in Sub-Saharan Africa (USAID)

- "How and to what extent do farmers access and use weather and climate information to inform their decisions?
- What impact do WCS have on farmer's livelihoods and on agricultural development goals?
- How do particular aspects of the design and implementation of WCS influence their effectiveness?"

Annex 2 – Step-wise adaptation practices

2.1 – Methodology

- Tuesday 9th of April - Interview with Mr. David Mukasa from International Institute of Tropical Agriculture (IITA), partner of HRNS.

2.2 – Project

Alliance for Resilience Coffee Project: enhancing adoption of CSA practices for sustainable Coffee productivity. One step at a time

Giving the high level of uncertainty in the climate projections, HRNS in tandem with IITA, has recommended a "no-regret stepwise Climate Smart coffee (CSC) pathway for adaptation. This path basically provides farmers with a sequence of agronomic practices, "in which each step requires additional effort". HRNS and IITA have set up four trial projects in the Luwero district. The main objective of these trial projects is to make farmers direct understand the yield gain due to the uptaking of this specific adaptation practices, regardless the poor recent climate condition.
Each project has consisted in the identification of four different areas in the same farm, with a different level of effort (figure 39):

1. ***The control area***: It is a site where the business as usual technique is maintained.
2. ***The step 1 area:*** this area requires a very basic intervention effort. Weeding, de-suckering and planting shade tree are the key operations of this step.
3. ***The step 2 area:*** it is an area where to all activities performed in the step 1, farmers need to create trenches (to increase water retain), use pests and diseases control, manure and prune trees.
4. ***The step 3 area***: as additional operation, farmers need to use mulching.
5. ***The step 4 area:*** use of fertilizers and again chemical pests and disease control is required.

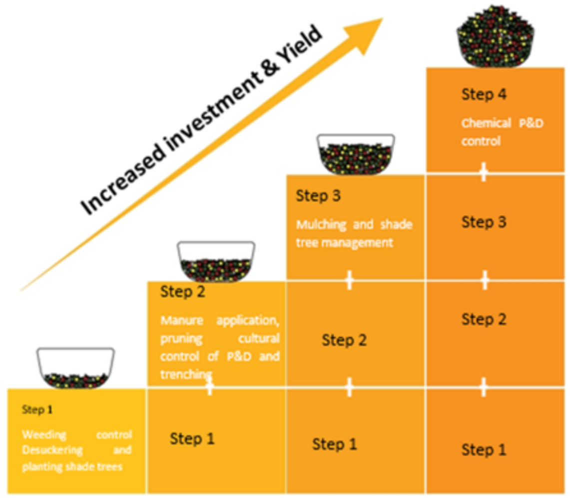

Figure 39 - Step-wise adaptation path. Source IITA

According to IITA all these steps should improve the microclimate condition and thus boosting yields. The preliminary yields results are promising (figure 40) in the same climate condition, the control site has recorded a production of 711 kg/ha whilst on the step 4 area the yield has increased by 76% or 1257 kg/ha

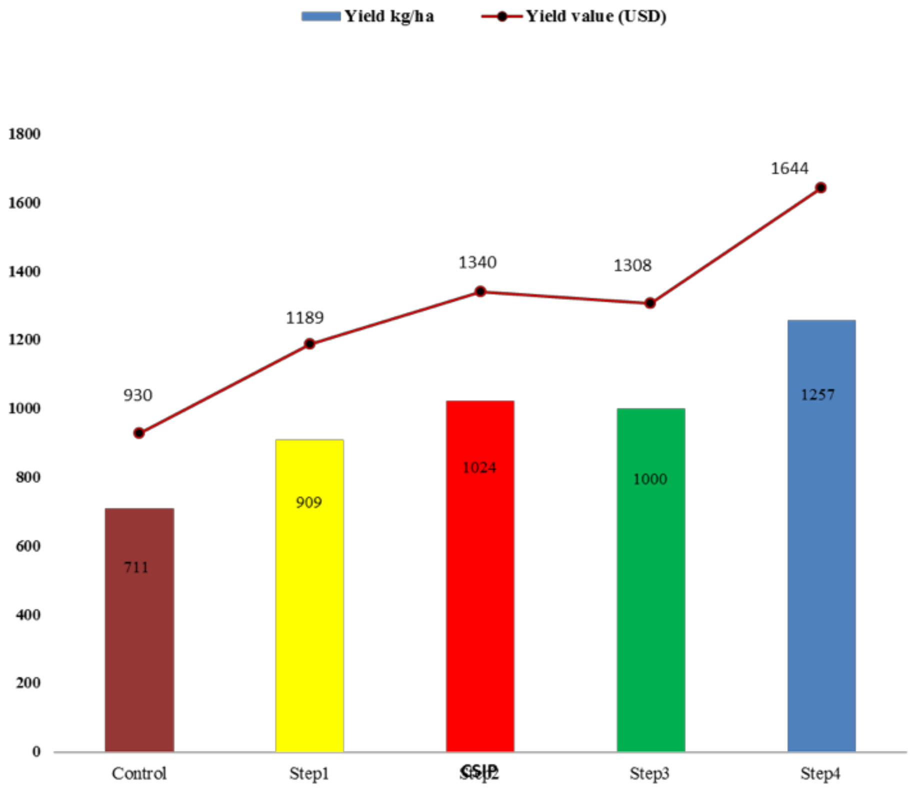

Figure 40 - Step-wise adaptation practices Yield results. IITA source

2.3 – Photo voice

1. Nalugooti Gertrude Musoke. 32 years old. (Farmer/demo host) Katikamu subcounty, DC extensionist

Figure 41 –Starting from Left: Mrs. Nalugooti Gertrude Musoke and Mr. Victor Komakech. 1sr Interview. Picture of Mr. Joffrey from HRNS

Figure 42 – Rain Gauge. Rainfall monitoring. This part of the project requires farmers to write on a paper every two days at 9am the total amount of rain. Picture of Filippo Radice

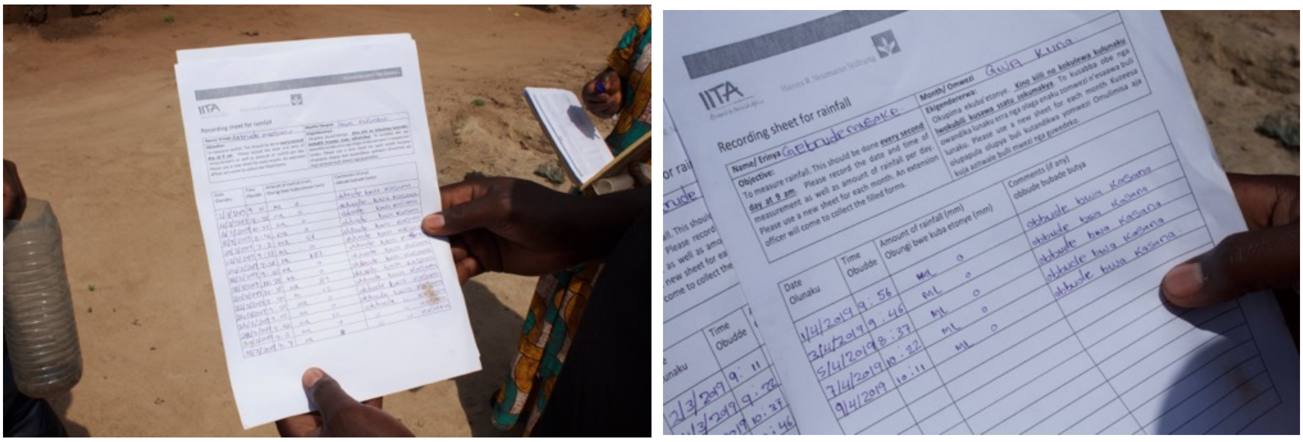

Figure 43 - Rain Gauge. Rainfall monitoring. Left: in March they have detected rain on the 10th, 14th 20th, 22nd, 28th and 31st respectively 56mm, 187mm, 89mm,12mm, 15mm, 3mm. Right: April, at the 9th of April no rainfall has been recorded. Picture of Filippo Radice

Figure 44 – Left: Trenches for water conservation. Right: shade tree. Picture of Filippo Radice

Figure 45 –Left: "Fly coffee" for the mbirabira season. Right: unripe coffee beans. Picture of Filippo Radice

2. Ssekandi Daniel Godfrey 50 years old (Farmer/demo host) Katikamu subcounty, DC extensionist

Figure 46 – Mr. Victor Komakech and Mr. Ssekandi Daniel Godfrey during the interview. Picture of Filippo Radice

Figure 47 –Control site. Left: identification of the control site. Right: a dry coffee tree. Picture of Filippo Radice

Figure 48 - Step 1 area. Left: identification of the step 1 area. Right: a coffee tree in the step 1 area. Picture of Filippo Radice

Figure 49 - Step 4 area. Left: identification of the step 4 area. Right: coffee trees with hives for cross-pollination in the step 4 area. Picture of Filippo Radice

Figure 50 - Step 4 area. Water conservation. Picture of Filippo Radice

Figure 51 - Coffee trees in a step 4 area. Picture of Filippo Radice

3. Bazannyanengo Alooni Kiyaga 63 years old (Farmer). Katikamu subcounty, The Chair of the DC committee

Figure 52 – Mr. Bazannyanengo Alooni Kiyaga. Picture of Filippo Radice

Figure 53 - Shade grown coffee. Left: Banana tree. Right: Milicia Excelsa. Picture of Filippo Radice

Figure 54 - Mr. Bazannyanengo Alooni Kiyaga explaining the importance of water conservation. Picture of Filippo Radice

Figure 55 - fly coffee for the mbirabira season. Picture of Filippo Radice

Figure 56 – Left: fly coffee harvested for the mbirabira season. Right: fly coffee beans. Picture of Filippo Radice

4. Ssalongo Kigongo Fred. 53 years old (Farmer/demo host). Butuntumula subcounty

Figure 57 – Mr. Ssalongo Kigongo Fred. Picture of Filippo Radice

Figure 58 –full adoption of adaptation practices. Picture of Filippo Radice

Figure 59 –Coffee trees of neighbors that are not taking any adoption practices. Picture of Filippo Radice

References

- Abayomi Samuel Oyekale. *Access to risk mitigating weather forecasts and changes in farming Operations in East and West Africa: Evidence from a Baseline Survey*. October 2015. https://www.mdpi.com/2071-1050/7/11/14599
- Bakama B. BakamaNume. *A Contemporary Geography of Uganda*. Prairie View A&M Univeristy. 2010. https://books.google.com/books?hl=en&lr=&id=E-u-oqGczPsC&oi=fnd&pg=PP1&dq=geography+uganda+altitude+plateau&ots=NEHGReeNph&sig=URlYCiYxF9CgvPeVLugMOQamubM#v=onepage&q=geography%20uganda%20altitude%20plateau&f=false
- Ben Orlove, Carla Roncoli, Merit Kabugo. "*Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system*". November 2007. Springer. https://link.springer.com/article/10.1007/s10584-009-9586-2
- Carl J. SCHREK III and Frederick H. M. Semazzi. *Variability of the recent climate of eastern Africa*. 2004. https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/joc.1019
- David P. Rowell and Ben B. B. Booth. *Reconciling Past and Future Rainfall Trends over East Africa*. December 2015. https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-15-0140.1
- Famine Early Warning Systems Network – Informing Climate Change Adaptation Series. *A Climate Trend Analysis of Uganda*. June 2012. https://pubs.usgs.gov/fs/2012/3062/FS2012-3062.pdf
- Francis Wasswa Nsubuga, O.J. Botai, Jane M. Olwoch, C.J. deW Rautenbach, Yvette Bevis and Adebayo O. Adetunji. *The Nature of rainfall in the main drainage sub-basins of Uganda*. February 2014: https://www.tandfonline.com/doi/full/10.1080/02626667.2013.804188
- Francis Wasswa Nsubuga, Hannes Rautenbach. *Climate Change and variability: a review of what is known and ought to be known for Uganda*. December 2017. https://www.emeraldinsight.com/doi/full/10.1108/IJCCSM-04-2017-0090
- Irish AID, Resilience and Economic Inclusion Team, Policy Unit. *Uganda Country Climate Risk Assessment Report*. February 2018 https://www.climatelearningplatform.org/sites/default/files/resources/uganda_climate_risk_assessment_report_-_final_version.pdf

- Katharina Waha, Birgit Zipf, Pradeep Kurukulasuriya & Rashid M. Hassan. *"An agricultural survey for more than 9,500 African households*". May 2016. https://www.nature.com/articles/sdata201620
- Maximus B. Byamukana, Mary Nsabagwa, Richard Okou, Julianne Sansa Otim, James B. Magezi-Akiiki. *Report on the Status of Weather Stations in Uganda.* https://wimea-ict.net/downloads/reports/RC3_05072015_Survey%20Report_Final.pdf
- Michele Bernardi, Eduardo Gelcer and Maurizio Bacci. *Handbook On Climate Information for farming communities.* Food and Agriculture Organization of the United Nations. 2019. http://www.fao.org/3/ca4059en/CA4059EN.pdf
- Rob Marchant, Cassian Mumbi, Swadhin Behera and Toshio Yamagata. *The Indian Ocean dipole – the unsung driver of climatic variability in East Africa.* 2006. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2028.2006.00707.x
- Sharon E. Nicholson. *The ITCZ and the Seasonal Cycle over Equatorial Africa.* March 2018: https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-16-0287.1
- Uganda Bureau of Statistics. 2018 Statistical abstract. January 2019. https://www.ubos.org/wp-content/uploads/publications/01_2019STATISTICAL_ABSTRACT_2019.pdf
- Uganda Coffee Development Authority. Fine Robusta Standards and Protocols. June 2010. https://coffeestrategies.com/wp-content/uploads/2015/04/compiled-standards-distribute1.1.pdf
- United Nations Development Program. *Environment and Natural Resources Report Series: enhancing the contribution of Weather and Climate Change to growth, Employment and Prosperity.* 2009. https://www.unpei.org/sites/default/files/e_library_documents/uganda-contribution-weather-climate-climatechange-final.pdf
- United Nations Development Program. *Uganda Annual Report 2017.* October 2018. http://www.ug.undp.org/content/uganda/en/home/library/undp-in-uganda-/UNDP_Uganda_Annual_Report_2017.html

- Vaughan C., Hansen J., Roudier P., Watkiss P., Carr E. Evaluating agricultural weather and climate Services in Africa: Evidence, methods and learning agenda. December 2017. https://www.climatelinks.org/file/3934/download?token=CWI76OPM
- Wilson Gitau, Pierre Camberlin, Laban Ogallo and Emily Bosire. *Trends of intraseasonal descriptors of wet and dry spells over equatorial eastern Africa*. July 2017. https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/joc.5234
- World Bank Group. *Developing the Agri-Food System for Inclusive Economic Growth*. November 2018. http://documents.worldbank.org/curated/en/678231542382500879/Uganda-Economic-Update-12th-Edition-Developing-the-Agri-Food-System-for-Inclusive-Economic-Growth