FINAL TECHNICAL REPORT FOR SCALING-UP PATHWAYS OF LAST MILE CLIMATE INFORMATION SERVICES FOR COMMUNITY RESILIENCE IN UGANDA AND KENYA

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Scaling-Up Pathways of Last Mile Climate Information Services for Community Resilience in Uganda and Kenya (CHAI-III)

Final Technical Report

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Acronyms and Abbreviations

ASDSP	Agricultural Sector Development Support Program
ATDC	Agricultural Technology Development Centre
B/C ratio	Benefit-Cost ratio
CCAFS	Climate Change, Agriculture and Food Security
CCD	Uganda Climate Change Department
CGIAR	Consultative Group on International Agricultural Research
CHAI	Climate Change Adaptation and ICT
CSA	Climate Smart Agriculture
DLG	District Local Government (Uganda)
FAO	Food and Agriculture Organization
FHI 360	Family Health International
GoK	Government of Kenya
ICT	Information and Communication Technology
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agricultural and Livestock Research Organization
KCCA	Kampala Capital City Authority
KES	Kenya Shillings
KMD	Kenya Meteorological Department
KSMS	Kenya School of Monetary Studies
MoWE	Uganda Ministry of Water and Environment
NGOs	Non-Governmental Organizations
NDMA	National Drought Management Authority
SMS	Short Message Service
SOMREC	Makerere University School of Medicine Institutional Review Board
TAHMO	Trans-African Hydro-Meteorological Observatory
ToT	Trainer of Trainers
TV	Television
UBC	Uganda Broadcasting Corporation
UCH	Uganda Chartered HealthNet
UN	United Nations
UNCST	Uganda National Council for Science and Technology
UN DESA PD	United Nations, Department of Economic and Social Affairs, Population Division
UNFCCC	United Nations Framework Convention on Climate Change
UNMA	Uganda National Meteorological Authority
UoE	University of Embu
WDR	World Development Report
WHO	World Health Organization
WFP	World Food Programme

1. Synthesis

There is a global consensus that unless urgent action is taken, the bad food security and extreme poverty situation in Kenya, Uganda and the rest of Africa will be aggravated by climate variability and change. According to the Intergovernmental Panel on Climate Change (IPCC), the best way out for the two countries and the continent is to adapt to climate change because adaptation will guarantee benefits now and in future. However, adaptation is information-intensive, and farmers in Kenya and Uganda and other parts of Africa lack access to climate information in user-friendly formats and within an acceptable lead time to enable them to make informed decisions to minimize losses and maximize on the opportunities presented by climate variability and change. The *Scaling-up Pathways of Last Mile Climate Information Services for Community Resilience in Uganda and Kenya Project* (CHAI III) project aimed to bridge this gap.

Started in June 2018, the project aimed to increase resilience of smallholder farmers in Kenya and Uganda by increasing access to climate change adaptation information using ICT-based platforms. In Kenya, the project was implemented in Machakos, Makueni and Kitui Counties. In Uganda, the implementation sites included Nakasongola, Sembabule, Soroti, and Rakai districts.

This final technical report covers the period from June 2018 to the end of the project July 2022. The report describes the accomplishments and research findings of the project including baseline study to understand needs and design activities, the dissemination of weather forecast-informed agricultural advisories to smallholder farmers in the intervention areas, conducting mother-baby trial and analyzing trial data to assess efficacy of adopted adaptation options, and the establishment of Climate Field Schools in Kenya.

In **Kenya**, the project developed and disseminated weather-based agro-advisories using local FM radio stations, agricultural extension staff, farmer meetings and pamphlets for the March-April-May (MAM) and October-November-December (OND) seasons. The project established and provided ongoing support to seven Climate Field Schools (CFS) for diffusing the adoption of improved agronomic practices. Majority of the farmers in the intervention areas used the advisories to plan their farm operations and are expecting to harvest good crops of pulses (pigeon pea, beans, cowpeas, and green grams), pearl millet among other drought-tolerant crops. Similarly, majority of the farmers (93.2%) in the three counties were aware of the recommended climate change adaptation measures and most of them adopted most of the key coping strategies recommended by the project team such as mixed farming/ integrated farming systems (23.36%), intercropping (16.88%), crop rotation (15.09%), agroforestry (12.82%), conservation agriculture (11.99%), crop diversification (10.06%) and water harvesting (9.79%). The three Counties of Machakos, Makueni and Kitui have embraced the agro-advisory service and have developed Climate Information Service Plans to institutionalize and finance the service. The project team was part of this process.

In **Uganda**, the project disseminated seasonal, 1-month and 10-day weather forecasts and agricultural advisories to smallholder farmers using FM radio broadcasts, SMS, email, and face-to-face farmers meetings with extension agents for March–April-May (MAM) and September–October-November-December (SOND) seasons for throughout the project period. The project conducted a study to determine the yield and profitability of different adaptation options for promotion in the drought-prone cattle corridor area. The study was conducted in Rakai and Nakasongola districts. Variables included: planting date (onset vs late/delayed); varieties of beans (NABE 4 NAROBEAN 2), and maize (Longe 5 and Bazooka); intercropping versus pure/sole stand; water harvesting, use of cattle manure plus mineral fertilizers (DAP and urea). The experimental design was split-split factorial Randomized Complete Block Design (RCBD), replicated six times. The project found that early planting is a critical decision that farmers should make; late planting resulted in a 43% decrease in gross margins. The study further found that water management is necessary, particularly for maize. Fertilizer (DAP, urea) use was more beneficial when the two crops are early planted; for late planted crop, manure use was a better option. Intercropping, though reduces yields of both maize and beans, was more profitable than the two crops grown in pure stand.

In Kenya, the project supported four graduate students: two graduated and have since enrolled for PhD programs, one has submitted his Masters Thesis for examination while another one was finalizing his Master Thesis. In addition, the project managed to publish four papers (three by Kenya team and one by Uganda team) in peer reviewed journals and three more manuscripts are under preparation. A book chapter was also in press showing the research findings of the project in Uganda. In a nutshell, the project was able to implement the proposed activities and achieve all its objectives. Going forward, the project team proposes to IDRC to consider increasing both the allocation of funds and the duration of the project for future climate change adaptation projects if they are to create the desired impact. The three-year funding cycle was insufficient considering that benefits from adaptation projects take a long period to accrue.

2. Research Problem

As is the case in African countries, Kenya and Uganda depend on agriculture for economic development and poverty alleviation. The agricultural sector accounts for over 17% of their Gross Domestic Product and employs over 60% of the total labor force with a majority being women and the youth. In addition, over 80% of their population lives in rural areas and depends mainly on agriculture for their livelihood. Agriculture, therefore, is not only key to economic growth but also a determinant of equity in development and fundamental to reducing poverty and hunger in the two countries (GoK, 2016; World Bank, 2016). The population in both countries is projected to double in the next 20 years (UN DESA PD, 2017). To feed the swelling population, an increase of over 100% of agricultural productivity is a must. Given the current trends in agricultural growth and the findings of a World Bank study (WDR, 2008), this is a formidable challenge. Crop yields in the two countries have stagnated over the years leading to a decline in per capita food production. Cereal yields rarely exceed 1.5 tons per hectare, especially in Kenya, less than half of those realized in other parts of the world. Thus, about 30 % of their population is chronically hungry and over 40% live in absolute poverty (Grebmer et al., 2017; United Nations, 2017; FAO GIEW, 2017; WFP, 2017; FAO/IFAD/WFP, 2015).

The low per capita food production in the two countries is mainly due to reliance on rain-fed agriculture, which is vulnerable to climate variability and change; occurrence of more frequent and intense droughts; low investment in the sector; limited access to technology; and poor rural infrastructure among other reasons (Grebmer *et al*., 2017; Serdeczny *et al*., 2015). Achieving an accelerated agricultural growth rate is imperative to enable these countries to minimize widespread poverty, malnutrition and food insecurity (WFP, 2017). With most of the high agricultural potential areas already over-populated, much of the required growth is expected to come from intensive cultivation of arid and semi-arid areas which constitute over 70 % of their total area (Grebmer et al., 2017; GoK, 2016). However, cultivation of these areas is widely viewed as difficult due to water scarcity and other biotic and abiotic constraints that undermine agricultural productivity and resilience. Rainfall in these areas is low and very erratic due to climate variability and change (Gichangi *et al*., 2015). Consequently, most smallholder farmers are unwilling to invest in recommended agricultural productivity-enhancing technologies due to uncertainty on returns on their investments (Itabari *et al*., 2011; Cooper *et al*., 2009; 2008). This threat can be overcome using two approaches: the use of seasonal climate forecasts for risk reduction (for example, choosing seed varieties that can perform well for expected rainfall conditions), and the use of innovative financial instruments for risk sharing (for example, index-based weather insurance bundled to microcredit for agricultural inputs).

Several pilot studies conducted in these areas have shown that in situations where important farm decisions are to be made before the start of a season; and where favorable outcomes are highly dependent onto favorable amount and distribution of rainfall during the season, advance information about the rainfall during the forthcoming season has the potential to help farmers in these areas make advantageous decisions about farm investments and adopt management practices that make best use of the season and reverse the current food and poverty situation (Gebru *et al*., 2015; Rao and Okwach, 2004). High quality seasonal forecasts can help farmers tailor their crop management approaches to the anticipated seasonal conditions. Farmers will be able to make informed decisions about their investments such as restricting their investment during predicted bad seasons, and expanding when rainfall is good to ensure good returns from their farm. Farmers could also use seasonal and agricultural advisories to implement drought management plans prior to the event thereby acting in a proactive rather than reactive manner. However, for use at farm level the forecasts should be reliable, location-specific and available in a user-friendly format with sufficient lead time. In addition to seasonal forecasts, farmers require daily, 10-day and other short-range weather forecasts and agricultural advisories to guide in-season tactical decisions such as when to top-dress, spray, weed, thin, protect against excessive heat exposure, harvest etc. (Klemm and McPherson, 2017; Roudier *et al*., 2016; Tall *et al*., 2014; Hansen *et al*., 2014; Tall *et al*., 2013; Tall, 2013; Tall, 2012; Hansen *et al*., 2011; Tall, 2010). Currently, climate forecasts are released twice a year in Kenya (March-May and October-December) and twice a year in Uganda (March-May, June-August, and September-December), with a lead time of one month. Fortunately, because of tremendous development in numerical techniques, better understanding of physical processes and higher computational power seasonal forecasts and weather updates produced in both countries are sufficiently reliable for making farming decisions and are improving. However, the forecasts are usually too broad in their geographical scope, probabilistic in nature, inaccessible and incomprehensible to most farmers and their support agencies (Klemm and McPherson, 2017; Kusunose and Mahmood, 2016; Tall *et al*., 2014; Hansen *et al*., 2014; Tall *et al*., 2013; Tall, 2013; Tall, 2012; Hansen *et al*., 2011).

For over nine years, the Climate Change Adaptation and ICT (CHAI) project has endeavored to bridge this gap. The CHAI project had three phases. The first two phases were implemented in Uganda by FHI 360, Uganda Chartered HealthNet (UCH), Uganda's Ministry of Water and Environment and Makerere University through funding from the International Development Research Centre (IDRC) of Canada. The first phase of CHAI project (CHAI-1) was implemented from January

2012 to December 2014 whilst the second phase ran from October 2015 to February 2018. The third phase of CHAI, the focus of this report, was implemented from June 2018 to July 2022.

The first and second phases of the CHAI project used information and communication technology (ICT) tools to provide climate change adaptation information to more than 250,000 farmers in local languages in three intervention districts in Uganda, for the purpose of increasing the agricultural productivity of communities vulnerable to climate change. The project provided seasonal weather forecasts and agricultural information localized to the sub-county level; weekly livestock and crop market information to help farmers decide what, when, where and how much to sell; guidance on low-cost rainwater harvesting techniques; information on mechanisms to cope with droughts and floods; and termite-control measures.

The first and second phases of the project in Uganda, which engaged local and national stakeholders, delivered information through diverse communication channels such as interactive FM radio (broadcasts that allow farmers to ask questions or make comments through voice mail and text messaging, with responses later aired live during radio talk shows), text messaging, email, and community loudspeakers. Meetings with agriculture extension agents helped to reach an even broader audience. The initiative generated information on adaptation, disseminated location-specific information using multiple communication channels, supported farmers so they could act in response to the information they received and improved institutional processes. Importantly, the project continuously incorporated user feedback.

Studies conducted by first two phases of the CHAI project showed that access to adaptation information improved by up to 48 percent in the intervention districts (Nakasongola, Sembabule and Soroti) compared to the control district (Rakai), while the effectiveness of adaptation actions that were based on information received through the project increased by up to 33 percent in the intervention areas compared to the control district. The studies also showed that the use of timely and locally relevant adaptation information reduced crop loss and damage by 50-65 % in the intervention districts compared to the control district. As a result, the project was awarded the prestigious United Nations Framework Convention on Climate Change (UNFCCC) 2015 Momentum for Change's Lighthouse Activities Award, which recognizes innovative and transformative solutions addressing climate change and wider economic, social and environmental challenges. The award was conferred during the United Nations Climate Change Conference held in Paris on 30 November–10 December 2016.

However, although the CHAI model has gained credibility among farmers using it and several government agencies and won international recognition by the UNFCC, mechanisms for scaling it up to the rest of Uganda and other Sub-Saharan countries are yet to be determined. This is the key research gap that the third phase of CHAI (CHAI-III) sought to address – understanding how the delivery of ICT-mediated adaptation information to farmers can be used to increase the resilience and productivity of millions of vulnerable communities and agricultural systems in the region and deliver impact at scale. The overall goal of the project was to enhance the resilience of smallholder farming communities and households in Uganda and Kenya to the impacts of climate change. The specific objectives of the project included: (i) contribute to better understanding of the long-term costs and benefits of ICT mediated climate information services to small-holder farmers, (ii) assess effective strategies and pathways for scaling up

ICT mediated climate information services with multi-stakeholders within the public sector and intermediaries to inform future scale-up design, and (iii) examine the enabling environments and policy framework needed for ICT-mediated climate information services to advise current climate policy and legislatives processes in Kenya and Uganda, respectively. The project aimed to generate the following outcomes: (i) enhanced agricultural productivity and income among small holder farmers, and (ii) institutional arrangements for scaling up ICT mediated climate information delivery services operationalized.

3. Project Implementation and Management

The project was implemented in Uganda and Kenya for a period of 4 years (June 2018 to July 2022). In Uganda, the project was carried out in Soroti, Nakasongola, Sembabule, and Rakai districts. The intervention districts in Uganda were selected in close consultation with the Climate Change Department, Wetlands Management, and the Uganda National Meteorological Authority (UNMA) of the Ministry of Water and Environment. Selection criteria included (i) Districts experiencing water stress: The selected Districts lie in the cattle corridor which constitutes one of the most fragile ecosystems in the country and where climate change-induced water challenges are evident, (ii) Districts lying in different Water Management Zones: To facilitate sustainable and integrated water resources management, MWE divided the country into four Water Management Zones delineated based on topography, drainage demand patterns, water stress, and potential water conflicts in each zone. The four Water Management Zones are: Kyoga (Eastern), Victoria (Central), Albert (Western), and the Upper Nile (Northern) Zone. The selected districts lie in two water management zones. Soroti and Nakasongola are in the Lake Kyoga zone, Rakai and Sembabule are in the Lake Victoria zones. These zones are characterized by severe water stress. The other two water management zones are outside of the cattle corridor, (iii) Districts overlapping with Uganda National Adaptation Programs of Action (NAPA) study sites: Nakasongola, Soroti, and Rakai are among the 12 districts where climate-related data was gathered for the preparation of the Uganda National Adaptation Programs of Action (NAPA), which was the basis for responding to immediate and urgent adaptation needs. The selected districts represented a range of water management, hydro-climatic and climatologic, and agro-ecological conditions. This diversity helped to ensure that the research was undertaken in diverse settings making the study findings of the research more representative of the national situation. The four intervention districts have bimodal rainfall. In Nakasongola, the two rainy seasons occur March - July and the second season August – November. Rainfall amount ranges from 500 to 1,000 mm per year with unreliable onset and cessation. Temperature in Nakasongola ranges 18 to 35^0C. In Rakai and Sembabule, the two growing seasons are March – May and September – December. Its annual rainfall ranges from 915 5o 1,021 mm/year while temperature ranges from 13 to 30^0C. In Soroti, the two growing seasons are March – July and September – November. Annual rainfall ranges from 1,000 to 1,500 mm. The district records a mean annual maximum temperature of 31^0C with a minimum of 18^0C and maximum of 35^0C.

In Kenya, the work was carried out in Machakos, Makueni and Kitui Counties situated in semi-arid Kenya. The intervention counties were selected because, together with other arid and semi-arid areas, they are more vulnerable to the vagaries of climate variability and change. Further, two pilot studies were conducted in these areas in 2007-2011 and 2011-2014 through support from IDRC and both studies established that farmers here could derive significant benefits from the use of climate information if it is interpreted for location specific needs and delivered in time and in a format that can be easily understood by them.

Machakos is generally hot and dry with bimodal distribution of rainfall. Average annual rainfall in Machakos is 698 mm of which 293 mm is received during the short rain season (March-May) and 283 mm during the long rain season (October-December). Though both short rain and long rain seasons receive similar amounts of rainfall, short rain seasons are more reliable than the long rain seasons and therefore more important for crop production. The annual average temperature ranges between 250C and 13.10C. Temperatures during short rain season are slightly lower than those during long rain season (Recha et al., 2012; Jaetzold et al., 2006; Rao and Okwach, 2004). In Makueni and Kitui, due to lower altitude compared to Machakos, the temperature regime at these locations is warmer. The average annual maximum and minimum temperatures are 28.7 and 17.1°C, respectively, about 4°C higher compared to Machakos. They receive an annual mean rainfall of 614 mm of which 337 mm is received during the short rain season and 195 mm during long rain season. Relatively lower rainfall and higher evapo-transpiration due to higher temperatures makes these locations more water stressed and riskier for crop production compared to Machakos (Jaetzold et al., 2006). Thus, Makindu and Kitui represent the future climate for Machakos. Agriculture in the three sites is mainly rain-fed and crop production is severely constrained by low soil moisture emanating from low and erratic rainfall, low levels of soil fertility and widespread practice of low input agriculture. Most of the rivers are seasonal and hence cannot supply water when it is most needed. Groundwater resources are not abundant and in many places, the water produced is saline. More than half of the land is under smallholding agricultural production system mainly growing maize, pigeon pea, sorghum, beans, cowpea, green grams, and fruit trees like mangoes. Livestock production includes cattle, chicken, and goats. Most of the agricultural production serves subsistence purposes. On average, there is a crop failure in two out of every five seasons. The average yield of cereals and legumes is less than 0.5 t/ha which is only a third of the potential yield.

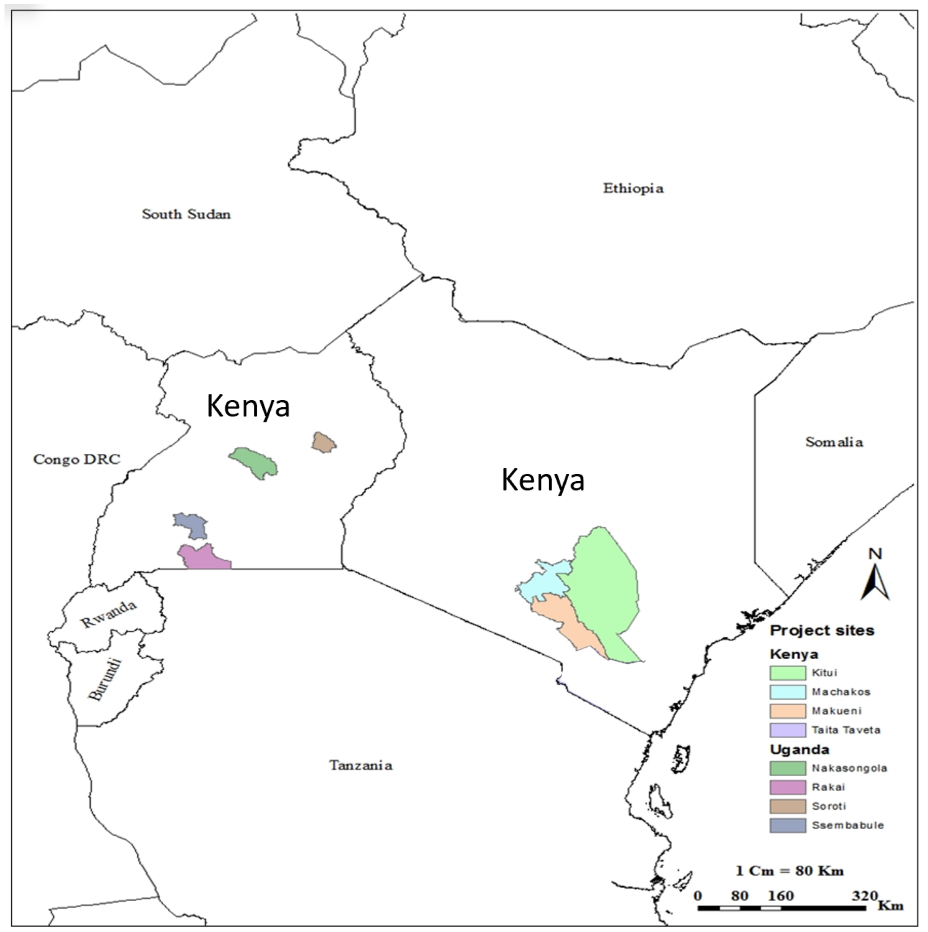

Figure 1: Intervention counties (Kenya) and districts (Uganda).

The start date of the project was supposed to be June 2018, however, at the beginning, project implementation did not proceed as envisaged. Contract negotiations between KALRO and implementing partners (FHI 360 and Uganda Chartered HealthNet) took longer than initially anticipated to conclude thereby delaying the rolling out of the project implementation both at the regional and national level. Nonetheless, the contracts were concluded successfully, and the regional inception meeting was held on 21-25 January 2019 in Kampala-Uganda, during which the project was officially launched. Similarly, due to the COVID-19 pandemic, project activities were slowed down forcing the project to apply for a one year no-cost extension in order to complete them. Graciously, IDRC granted the extension and the project managed to successfully complete its field activities.

The project started with a baseline study jointly designed by researchers from Uganda, Kenya and FHI 360. The findings of the baseline study informed the research approaches adopted by the Kenya and Uganda research team. Both countries used mother-baby trials to determine adoption rates and profitability of different approaches for water management, fertility, type of planting (dry or wet planting) and time to plant. In Kenya, the team engaged graduate students in conducting research and as part of its capacity building plan, while in Uganda, the team relied on a network of researchers because tuition fees were not included in the budget. The project learned that supporting graduate students and engaging them in conducting research was more effective and it resulted in increased pool of researchers in the climate information sub-sector.

this project evolved essentially as two parallel projects, which adopted similar baseline studies but then carried out very different research. Perhaps you could include a reflection on the partnership and the extent to which the collaboration unfolded as expected, any challenges encountered and lessons learned.

This final technical report provides a summary of the project for both countries. For additional information, the **Kenya and Uganda country reports are provided as Attachment A and Attachment B** respectively.

3.1 Baseline Study

The project conducted baseline study to understand farmers' adaptation information needs in both countries. In **Kenya**, the baseline study involved 650 households and was conducted in Machakos, Makueni and Kitui counties to establish farmers' access to and utilization of climate change adaptation information. Humid, sub-humid and semi-arid areas were sampled to ensure a representation of the agro-ecological zones in Southeastern Kenya region. The data collection tool was designed to capture data on the types of information accessed; channels used to disseminate the information; constraints in accessing and utilizing received information; improvements required in information delivery to reduce climate risks, increase resilience and preparedness to climate variability and change; and households' willingness to pay for the information.

In **Uganda** the baseline study involved 609 households in Nakasongola, Soroti, Sembabule and Rakai districts. As in Kenya, the baseline survey aimed to establish farmers' access to and utilization of climate and agricultural information. The households were drawn from 32 villages each constituting an Enumeration Areas (EAs) in which the previous phases of CHAI Project were implemented. Sixteen of these EAs were inhabited by predominantly animal rearing households and remaining 16 EAs predominantly crop growing areas. The sampling of the EAs included: (i) sampling of one subcounty per district; ii) sampling of two parishes from sampled subcounty (one predominantly crops growing and the other predominantly animal rearing); iii) sampling of two villages per parish. From each sampled village, 20 households were randomly selected for the baseline survey.

The findings of the baseline study informed the development of adaptation information for farmers and the key findings are provided in the research findings section of this report.

3.2 Dissemination of Climate and Agricultural Information

The dissemination of location-specific and timely climate and agricultural information to farmers was a key strategy of the project to enhance their adaptive capacity to the impacts of climate change and variability. The provision of seasonal and short-term weather information and agricultural advisories to farmers was one of the major activities of the project throughout its implementation period.

In **Kenya**, the project developed and disseminated location-specific climate information and agricultural advisories for Machakos, Makueni and Kitui Counties. Seasonal forecasts were released twice a year (March-May and October-December) with a lead time of one month issued by the Kenya Meteorological Department (KMD). The advisories were disseminated using local FM radio stations, agricultural extension staff, climate field schools, farmer meetings and pamphlets. Majority of the farmers used the advisories to plan their farm operations and boost their harvests of crops such as pulses (pigeon pea, beans, cowpeas and green grams), pearl millet among other drought-tolerant crops.

In **Uganda**, the project sourced climate and agricultural information from the Uganda National Meteorological Authority (UNMA) and from the Department of Relief, Disaster Preparedness and Management at the Prime Minister's Office that publishes the Monthly National Integrated Multi-Hazard Early Warning Bulletin. Seasonal forecasts were released twice a year (March-May and September-December) with a lead time of one month by UNMA in collaboration with the project. In addition to seasonal forecasts, UNMA developed 1-month and 10-days weather forecasts localized to the subcounty level for Nakasongola, Sembabule, Soroti and Rakai districts. Agricultural advisories specific to sub-counties were generated by the Production Departments of the participating districts for dissemination to famers in four languages: Ateso, Luruli, Luganda and Lunyankole. The project used multiple channels for the delivery of such information including interactive radio broadcasts, email, SMS and face-to-face meetings between farmers and extension agents.

3.3 Trials to Test Adaptation Options

The project design included the use of a "mother-baby trial" approach to enable farmers choose adaptation actions suited for their farms and to test the different adaptation options under carefully controlled conditions for both on-farm and on-station demonstration. The approach involved extensive data collection and analysis from demonstration and on-farm trials to accurately quantify the impacts of the options tested. Mother-baby trial data were collected and analyzed in both countries. Additional details regarding the outcomes of the trial are provided under "Research Findings" of this report.

3.4 Project Students

One of the key activities of the CHAI III project was to build regional technical capacity on development and management of ICT-mediated climate change adaptation information delivery platforms through graduate training and research supervision. In **Kenya**, the project supported four masters' students at the University of Embu and University of Nairobi and their details are summarized below.

Table 1: List of graduate students supported by the project.

Student's name	University	Degree	Thesis Title	Status

Debra Akeyo	University of Embu	MSc. Agricultural Economics	Climate change adaptation information for improved agricultural productivity among smallholder farmers in Lower Eastern Kenya	Graduated & enrolled for PhD
Lydia Muriithi	University of Embu	MSc. Agricultural Economics	Adoption of selected climate smart agriculture technologies among smallholder farmers in Lower Eastern Kenya	Graduated & enrolled for PhD
Samuel Odikori	University of Nairobi	MSc. Agricultural Information Communication & Management	Evaluation of factors influencing farmers' access and willingness to pay for climate change adaptation information in South-Eastern Kenya	Submitted Thesis & waiting for defense
Rees Wambua	University of Nairobi	MSc. Agricultural and Applied Economics	An analysis of economic efficiency of leafy vegetable production under drip irrigation in South- Eastern Kenya's climate field schools	Writing-up Thesis

3.5 Climate Field Schools

The project team in **Kenya** established seven Climate Field Schools (CFS), a first of its kind I Kenya, to increase farmers' knowledge on climate change and improve their response to it. The majority of the CFSs have adopted drip irrigation to grow high value crops such as kales and spinach with remarkable success.

Figure 2: Drip irrigation at Climate Field School site in Machakos County.

3.6 Dissemination of Project Outputs

The key outputs of the project include the following.

Publications in peer reviewed journals and conferences: The project produced and published the following two papers in refereed journals and one during a conference (third on the list) by the **Kenya** team.

(i) Onyango, D., Mogaka, H., Ndirangu, S. and Kwena, K (2021). Household socio-economic factors influencing choice of agro-advisory dissemination pathways for climate change in semi-arid areas of Kenya. *Information Development*. *https://doi.org/10.1177/02666669211026005*

(ii) Muriithi, L.N., Onyari, C.N., Mogaka, H.R., Gichimu, B.M., Gatumo, G.N. and Kwena, K. (2021). Adoption determinants of adapted climate smart agriculture technologies among smallholder farmers in Machakos, Makueni and Kitui counties of Kenya. *Journal of Agricultural Extension, 25 (2):75-85.*

(iii) Mogaka, H., Onyango, D., Kwena, K. and Muriithi, L. (2021). Averting climate change crisis in Lower Eastern Kenya through weather-based advisories: are existing policies effective and supportive enough? *National Research Conference on Sustainable Use of Land and Natural Resources to Enhance Food Security in Kenya, 24-25 November 2021, Safari Park Hotel, Nairobi, Kenya.*

In addition, the following manuscripts were under preparation at the time of writing this report and will be published on peer-reviewed open-access journals that offer free publishing opportunities:

1. Onyango, D., Mogaka, H., Ndirangu, S. and Kwena, K. (2022). Climate change adaptation information and food productivity in the drylands of Kenya: Counterfactual analysis.
2. Muriithi, L.N., Onyari, C.N., Mogaka, H.R., Gichimu, B.M., Gatumo, G.N. and Kwena, K. (2022). Factors affecting multiple climate change adaptation practices in Lower Eastern Kenya: A case study of smallholder farmers.
3. Odikor, S., Nyanganga, H. and Kwena, K. (2022).Adapting to climate change in semi-arid Eastern Kenya: Are farmers accessing adaptation information?"

In **Uganda**, the following was published in a peer-reviewed journal and a book chapter pending publication as indicated below.

Onesimus Semalulu, Patrick Kibaya, Stewart Kyebogola, Edson Mworozi, Nelson Sewankambo, Berhane Gebru (2022). Profitability and Farmer Acceptability of Selected Climate Smart Technologies and Practices for Maize-Beans Production in Drought-Prone Areas, Uganda. Agricultural Sciences Vol.13 No.11, November 2022. https://www.scirp.org/journal/paperinformation.aspx?paperid=121516

Book Chapter
Onesimus Semalulu, Patrick Kibaya, Stewart Kyebogola, Edson Mworozi, Nelson Sewankambo, Berhane Gebru. Enhancing Farmer Resilience Through Profitable and Farmer-Acceptable Climate Smart Technologies and Practices. In Research Highlights in Agricultural Sciences (Book Chapter). Manuscript Number: 2022/BP/9255F. In Press at the time of submitting this report.

Climate and agricultural information:

Climate and agricultural information localized to subcounty level was generated for the March-April-May (MAM) and October-November-December (OND) seasonal rainfall forecasts issued by the Kenya Meteorological Department (KMD) and for March–April-May (MAM) and September–October-November-December (SOND) seasons for Uganda throughout the project period. This included seasonal forecasts, one-month and 10-day weather forecasts, and weather forecast-informed agricultural advisories such as types of crops to plant; guidance on low-cost water harvesting techniques; livestock and crop market information derived from local market outlets; and termite control advice to help communities avert livestock and crop losses.

Table 2: Summary of climate and agricultural information products and dissemination pathways

Climate and agriculture information	Description	Dissemination pathway
Seasonal climate forecasts downscaled to subcounty level	Released twice a year in Uganda and Kenya with a lead time of one month and downscaled to sub-county level.	The full content of the seasonal and 10-day forecasts was broadcast in local languages farmers via FM radio, printed bulletins, and SMS. Printed bulletins were posted in community gathering places. Summaries and

Localized short-range weather forecasts	Downscaled daily and bi-weekly or 10-day weather up-dates released localized by participating districts in Uganda and sub-counties in Kenya.	brief updates of the forecasts were disseminated via SMS to farmers and extension agents who use mobile phones. Face-to-face meetings were organized by extension agents to deliver forecasts and advisories to farmers.
Weather-based agro-advisories	Summary of climate change adaptation measures appropriate for a given season. Location-specific suggestions that help in minimizing losses and optimizing returns on investment. Adaptation options included improved drought resistant crop varieties, diversification, early planting etc. Content was developed by agriculture and climate experts and extension agents before the start of every season.	Advisories were broadcast via interactive FM radio transmissions where farmers are encouraged to call or use text-messaging to ask questions or request clarification. Summarized version of the advisories were disseminated via text messages to farmers and extension agents who use mobile phones. The full content of the advisories was posted on community bulletin boards and used by extension agents to guide face-to-face discussions with community members.
Crop and livestock market information	Weekly crop and livestock market prices from local market outlets aimed at helping farmers to minimize economic losses incurred by selling their products below the market value.	Weekly market information was transmitted via local FM radio stations and posted at community bulletin boards. A summary of the weekly market information was sent via text messaging to farmers, extension agents, religious institutions, NGOs, and CBOs.
Index-based crop and livestock insurance	Information on how index-based insurance works, how to access the services, its costs, benefits and risks.	Information was disseminated via interactive FM radio, text messaging, bulletin boards and face-to-face meetings between farmers and insurance agents.

Digital platform for information dissemination: The project used a digital platform in both countries for supporting the timely dissemination of climate and agricultural information in a user-friendly format that is comprehendible to the farmers. The platform supports information dissemination through SMS, interactive radio broadcasts, and Internet. To ensure sustainable use of the platform, the project engaged private local firms that provide bulk SMS services. Working with the private firms, the project developed a web portal for scheduling text messages to specific groups or to all farmers in the database, track history of sent information, and analyze delivery of text messages such as if and when the text message was opened by the farmer. The SMS delivery platform worked across mobile network operators to ensure that service is not tied to a single operator. County and district governments respectively in Kenya and Uganda can continue using the platform for the delivery of climate and agricultural information to farmers.

Climate Field Schools: In Kenya, the project established and provided ongoing support for seven CFS to train farmers and demonstrate improved agronomic practices.

Demonstration sites: In Uganda, the project established three mother-baby trial sites in three sub-counties. In Kenya, the study team established seven CFS-based demonstration sites and adopted one demonstration site from KARLO for demonstrating adaptation options to farmers.

Communications to the public: In **Kenya**, the project team held talk-shows on three local FM stations to discuss the project objectives and the benefits of downscaled forecast-based climate change adaptation information in increasing adaptation action and resilience of smallholder farmers. In **Uganda**, the project team held radio talk shows on four local FM radio stations in local languages in the four intervention districts.

Engagement of key partners: The project team in both countries engaged partners at the county-level in Kenya, and at national and district-level in Uganda to inform the partners on the status of the project and involve them in the planning and implementation of the project activities. The key partners included the following.

Table 3: Key partners in Uganda and Kenya

Uganda	Kenya
• Ministry of Water and Environment, Climate Change Department • Uganda National Meteorological Authority • National Agricultural research organization (NARO) • Ministry of Agriculture, Animal Industry and Fisheries • District Production Department, Natural Resources Department, Communications department • Local FM radio stations and mobile network operators • NGOs, CBOs, FBOs and Farmer Organizations	• Kenya Meteorological Department • University of Embu • University of Nairobi • Ministry of Agriculture • Agricultural Technology Development Centre • Agro-dealers • Local FM Radio stations and mobile network operators • NGOs, CBOs, FBOs and Farmer Organizations • Biovision Africa Trust • Kilimo Media International

During the COVID-19 pandemic, stakeholder engagements were primarily conducted via email, phone calls and Zoom meetings with limited face-to-face meetings. After the lifting of COVID-19 restrictions, the project team engaged the stakeholders through face-to-face meetings and interactions.

4. Research Findings

4.1 Baseline Study

At the beginning of the project, the research teams in both countries conducted a baseline study to establish farmers' access to and utilization of climate change adaptation information, understand the information and communication needs of the farmers, generate data and information that would inform project design, formulate project activities and targets, and thereby guide resource allocation and establish project baseline parameters and indicators that could be used to compare to end-line measures of the same indicator.

In **Kenya**, a baseline survey involving 650 was conducted in Machakos, Makueni and Kitui counties. The data collection tool captured data on type of information accessed, channels used to disseminate the information, constraints in accessing and utilizing received information, any improvements required in information delivery to reduce climate risks, increase resilience and preparedness to climate variability and change, and their willingness to pay for the information.

Results from the baseline survey show that 75% of the households in the project sites received seasonal weather forecast with information on onset and cessation of the rains, warning on extreme floods or drought. One month, five to ten days and one day forecasts were respectively accessed in 33%, 7% and 24% of the households. Radio was the most popular channel of disseminating the forecasts in 73% of the households while 9% received from agricultural extension staff and

Kenya Meteorological Department. Fifty two percent got advisories on appropriate crops to grow, fertilizer application and livestock management that resulted in increased production. The advisories were used in 48% of the households. However, more location specific information was required. Those who found the weather forecasts slightly reliable demonstrated by their willingness to pay for the information. The evaluation was disaggregated by gender of the household heads but there was no statistically significant association of gender of household head and the access to forecasts, use of advisories and its effects on farm yields. Capacity building of the farmers on interpretation of the weather information and its application in farm decision making and the use of index-based insurance to cushion against the climate risks was required to enhance the farmers' resilience to climate change. The baseline survey report for Kenya will be submitted separately.

In **Uganda**, baseline survey data was collected from 609 households across the five[1] study districts (Nakasongola, Sembabule, Soroti, Rakai and Kyotera). The baseline survey found that the main source of income for 92% of the households was farming. About 44% of the households had an alternative source of income with male headed households 1.6 times more likely to have an alternative source than female headed households. About 95% of the households reported experiencing drought over the past 12 months from the survey date. The other weather-related hazards included floods, damaging rains, wind and hailstorms which were more pronounced in Soroti as compared to the other study areas. All households reported experiencing agricultural losses attributable to weather

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[1] Baseline data was collected from the five districts, however, Kyotera is not an intervention district due to resource constraints.

related hazards with drought (57%) and delay start of rains (23%) reported as the most common impediments to agricultural productivity.

On average, about 43% of the households reported to have received climate and agricultural information. Though not significantly different (p=0.134), a relatively higher proportion of male headed households reported receiving climate information than female headed households (male headed=44%, female headed=38%). About 67% of the households indicated that FM radio broadcast was the main source of climate and agricultural information followed text messages (16%). Other sources of information such as direct information exchange from farmers, extension agents, and community-based organizations and NGOs constituted about16%. Of the households who received climate and agricultural information, about 70% indicated that received information was relevant and 64% indicated it was effective for increasing agricultural production. The most common adaptation action employed by the households was planting drought resistant and early maturing crops. Respondents who used coping methods such as planting of drought resistant crops, early planting, irrigation, and water harvesting found the mechanisms to be efficient and effective.

The respondents indicated that access to affordable loans was one of the major impediments to acting on received climate and agricultural information. However, only 16% of the households acquired a loan to manage the effects of climate change. The respondents reported using loans for buying resistant seeds (31%), farm implements (14%), labor acquisition (13%), land hire (10%) and payment of school fees (7%).

Agricultural insurance schemes have been introduced in Uganda to minimize financial losses suffered by farmers from damage and destruction of their crops and livestock. However, none of the sampled households have signed for crop or livestock insurance in the reference period of 12 months prior to the survey date. About 20% of the household's willingness to pay premiums for crop insurance coverage.

4.2 Effectiveness Climate and Agriculture Information Service and Field Demonstrations in Enhancing Adaptation and Productivity

Timely access to location specific climate change adaptation information in a user-friendly format has been a major challenge to farmers in Kenya and Uganda and Africa in general. To address this problem, as noted in previous sections of this report, the project developed and disseminated location-specific advisories for to farmers in project locations based on down-scaled seasonal rainfall forecasts for March-April-May (MAM) for both countries, October-November-December (OND) for Kenya, and September-October-November-December (SOND) for Uganda throughout the project period. The advisories were disseminated using local FM radio stations, agricultural extension staff, farmer meetings, local administrators, churches, and pamphlets. The aim was to help farmers to plan their farm operations well to minimize losses and maximize productivity in bad and good seasons, respectively. In addition, the project set-up field experiments to demonstrate the benefits of these agro-advisories to farmers.

A study was conducted towards the end of the project to determine the effectiveness of this agro-advisory service and field demonstrations in enhancing adaptation and productivity in both countries.

In **Kenya**, the study was conducted to determine the level of adoption and factors that influence adoption of the various climate change adaptation measures disseminated by the project team to farmers every season in Machakos, Makueni and Kitui counties through the agro-advisories service. The study found that about 93.2% of the farmers interviewed were aware of the recommended climate change adaptation measures, however, only 47.4% had adopted and used them on their farms (Table 4). This could be attributed to lack of technology trust and technical capacity among the farmers, their socio-economic status, type of technology, and high cost incurred during uptake (Nyasimi *et al*., 2017).

Table 4: Awareness and adoption of the climate change adaptation technologies.

Variable	**Percentage Yes (%)**
Awareness	93.2
Adoption of climate change adaptation technologies	47.4

Majority of the farmers in the three counties have adopted most of the key adaptation measures recommended by the team such as mixed farming/ integrated farming systems (23.36%), intercropping (16.88%), crop rotation (15.09%), agroforestry (12.82%), conservation agriculture (11.99%), crop diversification (10.06%) and water harvesting (9.79%) (Table 5). These results coincide with the findings of Ryan and Elsner (2016), who noted agroforestry, water harvesting, conservation tillage, and adjustments in farming operations as the major adaptation strategies adopted by farmers in Africa.

Table 5: Main climate change adaptation practices adopted in Machakos, Makueni and Kitui Counties.

Adaptation practice	**Percentage (%)**

Mixed/integrated farming	23.36
Intercropping	16.88
Crop rotation	15.09
Conservation agriculture	11.99
Crop diversification	10.06
Water harvesting	9.79
Agroforestry	12.82

Adoption of these adaptation measures was influenced by sex and age of the household head, his/her level of education, and size of the household and farm (Table 6).

Table 6: Factors influencing farmers' adoption of climate change adaptation technologies

Variable	Intercropping βCoef P-value	Crop rotation βCoef P-value	Conservation agriculture βCoef P-value	Agroforestry βCoef P-value	Crop diversification βCoef P-value	Water harvesting βCoef P-value
Sex	0.367 (0.320)	1.431 (0.000)***	0.223 (0.555)	1.207 (0.009)***	0.353 (0.316)	0.241 (0.537)
Age	-0.676 (0.222)	-0.121 (0.461)	-0.430 (0.445)	-1.539 (0.065)	0.226 (0.068)*	-0.062 (0.912)
Education level	0.054 (0.503)	1.223 (0.003)**	0.024 (0.943)	0.018 (0.092)*	1.046 (0.065)*	-0.010 (0.922)
Household size	-0.010 (0.982)	0.371 (0.424)	0.540 (0,253)	-0.204 (0.731)	1.416 (0.020)**	0.898 (0.092)*
Farm size	0.290 (0.005)***	0.284 (0.040)**	0.368 (0.245)	0.221 (0.508)	-1.111 (0.629)	0.089 (0.194)

Reference category=Integrated/mixed farming system, Number of observations=383, Asterisks ***, ** and * signify significance at 1%, 5% and 10% level. LR chi^2 =203.584, Prob>X^2=0.000, Pseudo R^2 = 0.556, Log-likelihood=575.165

According to the study, most farmers received the climate change adaptation information (agro-advisories) through the radio (37.4%), followed by neighbors and friends (24.4), extension agents (14.1%), mobile phones (9.1%), television (8.9%) and from local administrators (6.1%) (Table 7). The findings corroborate those of Aldosari *et al*. (2019), who rated radio as the most reliable source of information. Several factors including gender, age, ownership of phones and radio, occupation of the household head among other factors significantly determined the pathway used by farmers to access agro-advisories.

Table 7: Sources of climate change adaptation information.

Source	**Percentage (%)**
Radio	37.4
Television	8.9
Mobile phone	9.1
Agricultural extension agents	14.1
Neighbors and friends	24.4
Local administrators	6.1

Generally, uptake of adaptation information involving soil and water conservation and crop variety adjustment had a significant positive impact on productivity. Regarding the policy environment required to promote the ICT-based agro-advisory service, poor institutional arrangements and lack of funding were identified as the weakest link in providing the service. Meanwhile, about 77.2% of the farmers were willing to pay for the agro-advisory service, out of which nearly 62% were ready to pay in cash. The mean willingness to pay in cash was 12.78 USD per year whereas payment in kind was dominantly through parting with about 67 kg of the maize produced per year, which is equivalent to USD18.40 at the current market price. According to the farmers interviewed, the willingness to pay for the service depends on the effectiveness of the climate change adaptation information disseminated by the service, farmer's knowledge on climate change adaptation, and access to climate change adaptation information. However, very old farmers were unwilling to pay for the information.

In **Uganda**, field trials were conducted in Nakasongola and Rakai districts during 2020 and 2021 to test the effect of different climate adaptation options (planting date, fertilizer use, varieties, and intercropping) on maize and beans yield and profitability. In addition, the study evaluated farmer-acceptability of the different interventions. Variables included: planting date (onset vs late/delayed); varieties of beans (NABE 4 NAROBEAN 2), and maize (Longe 5 and Bazooka); intercropping versus pure/sole stand; water harvesting, use of cattle manure plus mineral fertilizers (DAP and urea). The experimental design was split-split factorial Randomized Complete Block Design (RCBD), replicated six times. Data on crop yield and farmers' production costs, were collected. Summary of the findings of the trial are provided below.

Effect of planting date on maize and bean yields and profitability

Planting maize early resulted in significantly (P<0.001) higher grain yields compared to late planting during both years. Maize yields dropped by 16% due to late planting in both years (P<0.001). For beans, early planting resulted in significantly higher grain yield during 2021 season. There was 11% decline in grain yields during 2020 because of late planting. However, in 2021 bean grain yields dropped sharply by 46% due to late planting, which was highly significant (P<0.001). Planting beans late caused an 18 and 43% drop in benefit-cost ratio (B/C ratio) during 2020 and 2021, respectively. There was however an economic loss (BC=0.826) during 2021. For maize, late planting resulted in a significant (P<0.001) 14 and 28% drop in B/C during 2020 and 2021, respectively (Table 8).

Table 8: Effect of planting date on maize and beans profitability

	Beans		**Maize**	
Plating date	**2020**	**2021**	**2020**	**2021**
	Benefit-Cost (B/C) ratio			
Early	1.656 ± 0.055^{a}	1.446 ± 0.061^{a}	1.772 ± 0.056^{a}	1.675 ± 0.056^{a}
Late	1.353 ± 0.046^{b}	0.826 ± 0.039^{b}	1.517 ± 0.050^{b}	1.208 ± 0.050^{b}
% drop in B/C	18.3%	42.9%	14.4%	27.9%

[#] Means within the same column followed by the same superscript are not significantly different (P=0.05).

Effect of fertilizer application on maize and beans yield and profitability

During 2020, fertilizer application increased maize grain yields significantly (P<0.001), more so with manure compared to DAP or manure and DAP combination. During 2021, however, fertilizer application had no effect on maize yield (Table 9). The variations on yield for the same factors (planting date, fertilizer use, varieties and planting pattern) were influenced by seasonal variations of rainfall. On the other hand, bean yields significantly increased with application of DAP during 2020 and 2021, but not manure or manure and DAP combination. During 2020, use of DAP increased B/C ratio for beans, although not significantly (P>0.05). Use of manure on beans reduced the beans B/C, more so when combined with DAP (P<0.05). Similar results were obtained during 2021 (Table 10). For maize, application of DAP or manure did not improve B/C; in fact, combined use of manure and DAP on maize significantly (P<0.05) reduced the B/C ratio during both years.

Table 9: Effect of fertilizer application on maize and beans yield

	Maize yield, kg/ha		**Bean yield, kg/ha**	
Fertilizer treatment	**2020**[#]	**2021**	**2020**	**2021**
Control	$3467\pm104^{bc\#\#}$	2848 ± 77^{a}	515 ± 28.7^{b}	288.5 ± 20.7^{bc}
DAP	3958 ± 200^{b}	2987 ± 132^{a}	717 ± 56.6^{a}	463.4 ± 36.6^{a}

Manure	4904±302^{a}	3026±157^{a}	580±68.5^{b}	245.2±27.8^{c}
Manure+DAP	3369±201^{c}	2800±213^{a}	392±40.2^{c}	374.8±71.1^{ab}

#Means within the same column followed by the same superscript are not significantly different (P=0.05); ## ± value indicates standard error of the mean.

Table 10: Effect of fertilizer application on maize and beans profitability

	Beans		**Maize**	
Fertilizer treatment	**2020#**	**2021**	**2020**	**2021**
	B/C			
Control	1.553±0.054$^{ab\#\#}$	1.664±0.054^{a}	1.774±0.054^{a}	1.386±0.060^{a}
DAP	1.756±0.072^{a}	1.765±0.074^{a}	1.774±0.077^{a}	1.232±0.072^{a}
Manure	1.493±0.108^{b}	1.567±0.102^{a}	1.641±0.097^{a}	1.273±0.083^{a}
Manure+DAP	1.012±0.058^{c}	1.045±0.061^{b}	1.078±0.063^{b}	0.961±0.122^{b}

#Means within the same column followed by the same superscript are not significantly different (P=0.05); ## ± value indicates standard error of the mean.

Maize and bean yield and profitability for different varieties

Maize yields were significantly ($P<0.05$) higher for variety Bazooka than Longe 5 during both years, resulting in higher B/C for Bazooka than Longe 5 (Table 11). Bean yields and B/C were higher for NAROBEAN 2 than NABE 4, although not significantly different ($P>0.05$).

Table 11: Maize and bean yield and profitability as affected by difference in varieties.

	2020	**2021**	**2020**	**2021**
	Yield, kg ha^{-1}		**Benefit-Cost (B/C) ratio**	
	Maize			
Bazooka	4002^{a}	3075^{a}	1.727^{a}	1.456^{a}
Longe 5	3407^{b}	2735^{b}	1.562^{b}	1.427^{a}
	Beans			
NAROBEAN 2	568.0^{A}	345.3^{A}	1.511^{A}	1.161^{A}
NABE 4	529.0^{A}	316.1^{A}	1.498^{A}	1.111^{A}

#Means within the same column followed by the same superscript are not significantly different (P=0.05).

Effect of planting date and fertilizer treatment on bean yield and profitability, 2020

A significant (p=0.002) interaction was observed between time of planting and fertilizer application during 2020. Application of DAP significantly (p=0.002) increased the grain yields of early-planted beans over the control. When late planted, grain yields were significantly increased by application of manure without DAP (Table 12). Regarding profitability, results show that during a wet season (2020A), application of DAP increased B/C for the early-planted but not the late-planted crop. Manure use reduced the B/C for early planted beans, while for the late planted crop, a slight increment in B/C was observed. Combined application of DAP and manure further reduced B/C significantly, whether early or late planted.

Table 12: Bean yield and profitability as affected by time of planting and fertilizer application, 2020

	Bean yield, kg/ha		**Benefit-Cost (B/C) ratio beans**	
	Early[#]	**Late**	**Early**	**Late**
Control	545 ± 44.8^{b}[##]	486 ± 35.8^{b}	1.695 ± 0.083^{ab}	1.412 ± 0.067^{a}
DAP	795 ± 88.0^{a}	639 ± 70.7^{ab}	2.005 ± 0.112^{a}	1.507 ± 0.073^{a}
Manure	420 ± 61.0^{b}	740 ± 112.1^{a}	1.369 ± 0.135^{c}	1.617 ± 0.166^{a}
Manure+DAP	479 ± 62.6^{b}	304 ± 45.7^{c}	1.223 ± 0.067^{c}	0.801 ± 0.080^{b}

[#] Means within the same column followed by the same superscript are not significantly different (P=0.05). [##] ± value indicates standard error of the mean.

Interactive effects of fertilizer application and planting pattern on bean yields

Application of DAP increased bean grain yields, more so in pure stand. Manure use slightly improved bean yields both in pure stand and in intercrop, but not significantly. Combined use of manure with DAP reduced bean grain yields, especially in pure stand (Table 13). Regarding profitability, application of DAP significantly increased bean production B/C especially for the pure bean stand (P<0.05). Manure application had no effect on B/C whether in pure stand or intercrop. In fact, combined application of manure and DAP on beans, whether as intercrop or pure stand, decreased B/C.

Table 13: Effect of fertilizer application and planting pattern on bean yields and profitability, 2020

	Bean yields, kg/ha		**B/C**	
Fertilizer treatment	**Pure stand**	**Intercrop**	**Sole/pure stand**	**Intercrop**
Control	800±61.2^{b}	373±20.4^{ab}	1.236^{bc}	1.712^{b}
DAP	1181±100.1^{a}	482±40.5^{a}	1.768^{a}	1.750^{a}
Manure	969±124.4^{ab}	386±45.4^{ab}	1.356^{b}	1.561^{b}
Manure+DAP	659±79.2^{c}	260±26.7^{b}	0.938^{c}	1.049^{c}

$^{\#}$Means within the same column followed by the same superscript are not significantly different (P=0.05)

Effect of intercropping on maize-bean yield, land equivalent ratio (LER) and profitability

Maize and beans yields were higher in pure stand compared to intercrops during both years. Results show that intercropping reduced maize yields by 25 and 16% during 2020 and 2021, respectively. On the other hand, bean yields dropped by 57 and 52% during 2020 and 2021, respectively due to intercropping (Table 14). These yield reductions were highly significant (P<0.001). Land equivalent ratio (LER) values were significantly (P<0.001) greater than 1.0 for the intercrops during both years. The B/C ratios were consistently higher for sole maize than intercrop and lowest for pure beans (P<0.001).

Table 14: Effect of intercropping on maize-bean yield, land equivalent ratio (LER) and profitability.

	Maize yield$^{\#}$	**Bean yield**	**LER**		**Benefit-Cost (B/C) ratio**	
	---------------------------------- 2020 --					
Sole crop	4,440±159$^{a\#\#}$	882±45.3^{a}	1.000^{b}		Sole maize	1.743^{a}
Intercrop	3,337±93^{b}	381±15.8^{b}	1.241^{a}		Intercrop	1.596^{b}
					Sole beans	1.322^{c}
	-------------------------------------- 2021 --------------------------------------					

Sole crop	3,242±116^{a}	504±35.2^{a}	1.000^{b}		Sole maize	1.667^{a}
Intercrop	2,737±66^{b}	244±14.1^{b}	1.497^{a}		Intercrop	1.328^{b}
					Sole beans	0.750^{c}

$^{\#}$Means within the same column and year, followed by the same superscript are not significantly different (P=0.05); ## + value indicates standard error of the mean.

Interactive effects of fertilizer application and planting pattern on maize yield and profitability

Table 15 presents results on the interactive effects of fertilizer use and planting pattern on maize yield and profitability. Results show that during a low rainfall season (2021), maize yields were not significantly (P>0.05) improved by DAP or manure use, both in pure stand and in intercrop. Combined use of manure and DAP significantly (P<0.05) reduced maize yields in pure stand, but not in intercrops (Table 15). On the other hand, B/C ratio was reduced when DAP and/or manure were applied, both in sole/pure stand and in intercrop.

Table 15: Interactive effects of fertilizer application and planting pattern on maize yield and profitability.

	Maize, kg/ha		**Maize B/C ratio**	
Fertilizer treatment	**Intercrop**	**Sole**	**Intercrop**	**Sole**
Control	2685^{a}	3174^{ab}	1.425^{a}	1.905^{a}
DAP	2817^{a}	3328^{ab}	1.298^{ab}	1.292^{b}
Manure	2683^{a}	3713^{a}	1.307^{ab}	1.860^{a}
Manure+DAP	2905^{a}	2590^{b}	0.953^{b}	1.036^{b}

$^{\#}$Means within the same column, followed by the same superscript are not significantly different (P=0.05).

Regression models for maize-bean yield and profitability under different CSA approaches

During both seasons (2020 & 2021) beans yields were most influenced by planting pattern (intercropping vs sole cropping), fertilizer treatment (use of DAP) and planting date (early vs delayed/late, Table 16). Results also show that during a normal rainfall season (2020), planting pattern, fertilizer use (DAP) and planting date significantly influenced beans profitability. However, in case of a *predicted* low rainfall season (2021), bean profitability is most influenced by planting date and planting pattern; fertilizer use on beans is not profitable. It is worth noting that difference in varieties had no significant influence on bean yield and profitability during both years. For maize, all four factors (planting date, fertilizer use, varieties, and planting pattern) influenced yield and profitability during 2020. However, during a low rainfall season (2021) maize yield was most influenced by planting date, variety planted and planting pattern, and not fertilizer management. On the other hand, maize profitability depended on planting date, fertilizer management and planting pattern, but not on variety planted.

Table 16: Summary of best-fit multiple regression models for maize-bean yield and profitability under different CSA approaches.

Parameter	**Combination**	**Adjusted R^2**	**Cp**	**Planting date**	**Fertilizer treatment**	**Bean variety**	**Planting pattern**
				p values			
2020							
Bean yield	A[#]	31.5	37.5	-	-	-	0.000
	B[##]	37.7	7.0	0.073	0.000	0.271	0.000
B/C	A	10.7	36.2	-	0.000	-	-
	B	18.1	7.0	0.000	0.000	0.836	0.000
2021							
Bean yield	A	15.4	86.2	-	-	-	0.000
	B	31.5	7.0	0.000	0.000	0.477	0.000
B/C	A	16.8	70.5	-	-	-	0.000
	B	30.1	7.0	0.000	0.122	0.656	0.000
Parameter	**Combination**	**Adjusted R^2**	**Cp**	**Planting date**	**Fertilizer treatment**	**Maize variety**	**Planting pattern**
				p values			

2020							
Maize yield	A	9.9	68.1	-	-	-	0.000
	B	24.0	7.0	0.000	0.000	0.000	0.000
B/C	A	12.0	24.2	-	0.000	-	-
	B	16.7	7.0	0.000	0.000	0.018	0.046
2021							
Maize yield	A	4.9	26.0	0.000	-	-	-
	B	10.9	7.0	0.000	0.546	0.003	0.000
B/C	A	13.6	27.0	0.000	-	-	-
	B	19.7	7.0	0.000	0.000	0.685	0.000

A= Best model with single explanatory variable, B= Subset with four variables

Results of the mother-baby study in Uganda clearly demonstrated early planting of maize and beans increases yield and profitability, especially when DAP is applied. In case of delayed planting or during a predicted low rainfall season, manure use is beneficial and likely more profitable using cheap home-generated manure. Planting Bazooka in pure stand is as profitable as intercropping it with beans, meaning that for food security, a farmer is better off intercropping. Although intercropping reduces yields of both maize and beans, it is more profitable than beans grown in pure stand. Profitability was higher when CSA practices (early-planting, fertilizer use, intercropping and use of higher yielding varieties) are used in combination, rather than singly. Thus, in upscaling CSA practices, policy makers and practitioners need to be mindful of the costs associated with different technologies and practices, the target enterprise, its intended purpose, as well as the market dynamics, so that farmer's benefits are increased and their losses minimized.

Farmer acceptability of the different CSA technologies and practices

In Uganda, there were many lessons learned by farmers on different technologies and practices covered in this study and these varied significantly ($P<0.05$) from each other. Most farmers (40%) indicated that they had learned the importance of timely planting, 24% indicated advantages of the varieties used in the study, 21% had learned the use of fertilizers, while 14.7% mentioned cropping arrangement (intercrop vs sole crop).

Farmers gave several reasons for the lessons learned. For most farmers (42%) timely planting results in higher yields for the early planted crops and reduced risks of pest damage (15.8%); late planted crops are also affected by extreme weather events (15.8%) (Table 17). On varieties, 29.4% of farmers learned that they should plant Bazooka under good rains and Longe 5 if a drought is expected. Secondly, Bazooka produced two cobs, while Longe 5 produced one bigger cob, as noticed by 23.5% of the respondents. In addition, 17.6% of respondents reported a higher growth vigor with Bazooka, and that NAROBEAN 2 grows faster. Farmers learned the importance of using good quality varieties of seed. They reported better germination, drought tolerance, quicker maturity, higher yields than their usual home-saved seed, among others. In fact, by the time the team went for late harvesting, one farmer had already used seed from the early-planted beans to plant the next season's crop, and indeed the young crop was flourishing.

On fertilizers, 63% of farmers recognized that fertilizer use leads to higher yields, with 18.4% reporting manure use to be a good practice (3.7% indicated they would stop selling manure and use it in their gardens instead). One farmer in Nakasongola remarked “I earlier thought my land is not productive, but plots applied with manure grew much better. This has motivated me to start using manure since I have not been using it on my land and yet I keep piling it in my kraal over years”. Interestingly, 7.4% of famers recognized that fertilized plots are less affected by drought. Most farmers (61%) learned that monocropping of beans is better than intercropping. However, 22.2% learned that intercropping is better due to the double benefits it gives, while 5.6% indicated that intercropping is better when the crop is early planted.

Table 17: Reasons given for the farmers lessons learned.

Reasons	**Planting time**	**Variety**	**Fertilizer**	**Sole vs intercrop**
Higher yields for early planted crops	42.1	-	-	-
Timely planting reduces risks like pest damage	15.8			
Late planted crops affected by extreme weather events	15.8			
Early land preparation	10.5			
Early planted crops fetch higher prices	10.5			
Intercrop when early planted and not for late planting	5.3	-	-	-
Plant Bazooka under good rains and Longe 5 in drought prone conditions	-	29.4		
Two cobs for Bazooka but bigger for Longe 5	-	23.5	-	-
NAROBEAN 2 grows faster	-	17.6	-	-
Higher growth vigor with Bazooka	-	17.6		
All maize varieties good provided sufficient rainfall distribution	-	5.9	-	-
All varieties equally affected by drought	-	5.9	-	-
Fertilizer use leads to higher yields	-	-	63.0	
Manure use is good and gives higher yields	-	-	18.5	-
Fertilized plots less affected by drought	-	-	7.4	
Farmer to stop selling manure but apply in his garden	-	-	3.7	-
Bigger seed size with manure followed by DAP and least in unfertilized	-	-	3.7	-
Not beneficial to fertilize fertile fields	-	-	3.7	-
Sole cropping of beans is better than intercropping	-	-	-	61.1

Intercropping is better due to double benefits	-	-	-	22.2
Intercropping reduces bean growth	-	-	-	5.6
Appropriate spacing of maize and beans in mono and intercropping	-	-	-	5.6
Intercrop if early planted and vice-versa	-	-	-	5.6
Total	**100**	**100**	**100**	**100**

5. Impacts

In **Kenya**, most of the farmers in the three Counties of Machakos, Makueni and Kitui are now using weather-based agro-advisories to plan their farm operations and are able to realize bumper yields of maize, pigeonpea, beans, green gram and cowpea among other crops, even when the season is marginal. This has reduced dependency on relief food supplies by the Government and aid agencies. The generation and delivery of weather-based agro-advisories was integrated with Counties meteorological departments and extension services and it will continue after the end of the project.

The three Counties of Machakos, Makueni and Kitui have embraced the agro-advisory service and have developed Climate Information Service Plans to institutionalize and finance the service. The project team was part of this process.

Likewise, in Uganda, most of the farmers in the implementation districts adopted weather-based advisories and adaptation options demonstrated in field sites. The project found that the different Climate Smart Agriculture (CSA) practices including planting date, intercropping, fertilizer use (DAP, manure or a combination of the two), and varieties of maize and beans were adopted by farmers and showed higher profitability as a result of the adoption of the practices. Early planting was superior to late planting in crop yield and benefic/cost ratio, particularly for maize. Fertilizer (DAP) use was most profitable for the early planted crop; for the late planted crop, manure use was better. Intercropping was as profitable as sole maize crop, meaning that for food security, a farmer is better off intercropping the two crops. Highest benefits were obtained when the different CSA options were combined. Farmers appreciated the different interventions, with majority committing to adopt more than two of the CSA options demonstrated.

6. Recommendations

The project has shown the importance of weather-informed agricultural advisories to enhance the adaptive capacity of farmers and the importance of localizing weather forecasts at least to the sub-county level to make the advisories actionable by farmers. The project worked with relevant government entities to downscale forecasts to the required localization and package advisories in languages understandable to farmers. However, there is a limited capacity in terms of financial and human resources at government agencies. Therefore, there is need to improve the capacity of meteorological agencies and ministries of agriculture in both countries in weather data collection, analysis, localizing, packaging, and dissemination using digital tools and other traditional channels such as radio broadcasts to farmers.

The project team also proposes to IDRC to consider increasing both the allocation of funds and the duration of the project for future climate change adaptation projects if they are to create the desired impact. The three-year funding cycle is not sufficient considering that Natural Resource Management (NRM) benefits take long to accrue.

Because of travel restrictions due to the COVID-19 pandemic, the project was unable to conduct hands-on trainings and procure some equipment to enhance the capacity of the team and participating institutions, respectively, as envisaged. Thus, the project team proposes to IDRC to consider allowing the project team to spend the balance of unused funds to carry-out these activities because they still require this capacity going forward.

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8. List of Attachments

Attachment A: **Kenya Country Report and Attachments**

Attachment B: **Uganda Country Report and Attachments**