



**NATIONAL AGRICULTURAL  
RESEARCH ORGANIZATION**

Coordinating, Overseeing & Guiding  
Agricultural Research in Uganda



**IMPACT OF  
NARO BEAN & MAIZE  
TECHNOLOGIES  
ON FARMER LIVELIHOODS &  
CONTRIBUTION TO UGANDA'S ECONOMY**



**OCTOBER 2022**

Copies are available from:

NARO Secretariat,  
Plot 11-13 Lugard Avenue.  
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## AUTHORS

Damalie Akwango-Aliau, George Lukwago, Richard M. Ariong, Isaac Kiyangi, Isaac Obongo, Stella Adur, Stephen Angundubo, Juma Ndhokero, Harris Luzinda; Thelma Akongo; Damalie Magala; Sarah Mutonyi, Godfrey Bwanika, Anton Bua, Yona Baguma and Ambrose Agona.

### Contributors

Dr. Stanley Nkalubo (Breeder; Legumes programme, NaCRRI), Bonnet Kwemoi (Breeder; Cereals programme, (NaCRRI), Emmanuel Alengo (NaCCRI), Graceline Akongo (Ngetta ZARDI), John Etin, (ABIZARDI), Robert Gidoi, (BUGIZARDI), Mercy Nimusiima, (KAZARDI), Dr. Fred Ssekiwoko, (BUZARDI) Abbey Sseguya, (NAROSEC) Joshua Guina, (NAROSEC) Paul Mwaka, (NARL) Emmanuel Kimbowa (MAAIF), and Wilberforce Tumwesigye (NARL).

### Editors:

Dr. George Lukwago

Dr. Damalie Akwango-Aliau

Dr. Godfrey Bwanika

Dr. Isaac Kiyangi

### Citation:

Akwango-Aliau, D., Lukwago. G., Ariong, R.M., Kiyangi, I., Obongo, I., Adur, S., Angundubo, S., Ndhokero, J., Luzinda, H., Akongo, T., Magala, D., Mutonyi, S., Bwanika, G., Bua, A., Baguma, Y. and Agona, A. 2022. Impact of NARO bean and maize technologies on farmer livelihoods and contribution to Uganda's economy. Entebbe: National Agricultural Research Organisation. 143pp.

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ISBN: 978-9913-619-99-8

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## ABOUT NARO

National Agricultural Research Organization (NARO) is an agency of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) with the mandate to coordinate and oversee all aspects of agricultural research in the national agricultural research system (NARS) in Uganda. NARO was established as a body corporate by the National Agricultural Research Act of 2005, and comprises a Governing Council, a Secretariat and 16 semi-autonomous Public Agricultural Research Institutes (PARIs) spread across the various agro-ecologies in the country. NARO develops and disseminates agricultural technologies, innovations, and management practices (TIMPs) that aim to spur agricultural transformation and contribute to Uganda's economic development. The Research and Development (R&D) obligations are implemented through the semi-autonomous PARIs that include the National Agricultural Research Institutes (NARIs) and Zonal Agricultural Research and Development Research Institutes (ZARDIs).

NARO contributes to agro-industrialisation through generation of technologies and innovation for sustainable development while increasing access to agricultural research products and services to improve total factor productivity. NARO implements a research agenda with the objectives of increasing production and productivity; alleviating food and nutrition insecurity; improving access to markets and support to value addition for various commodities that contribute improvement of livelihood of farmers. This is achieved through promotion of TIMPs in crops, livestock, forestry, and fisheries as well as deliberate integration of indigenous knowledge with modern scientific methods in the research agenda such as biodiversity conservation and characterisation, and bio prospecting. In pursuit of its vision, mission and goal, NARO has, since its creation, generated 957 technologies, innovations and management practices aimed to agricultural transformation and national economic development.

**Vision:** A competitive society supported by a dynamic agricultural research innovation system

The vision is anchored on the government's aspirations to transform Uganda from peasantry to a modern and prosperous society. NARO's contribution, therefore, targets to build a climate resilient, food and nutrition secure, and economically competitive society.

**Mission:** To innovate for sustainable agricultural transformation

NARO's mission focuses on developing and promoting agricultural technologies and innovations for commercialization and industrialization thus leading to agricultural transformation. Internally, NARO continuously strives to build a reputable national agricultural research and innovation system that is competent and resilient in responding to national economic development aspirations.

**Goal:** To increase total factor productivity and access to agricultural research products and services for agro-industrialization and inclusive growth.

NARO generates safe and competitive technologies and innovations driven by markets and industry. This approach will maximize gains from production factors thus making chain actors have comparative advantage in the marketplace.

**Core Values: Inclusivity, Subsidiarity, Transparency, Accountability, and Excellence**  
To achieve the strategic direction, NARO is committed to upholding the stated principles and values:

**Inclusivity:** Inclusivity creates opportunities and conducive environment for all interested stakeholders to participate in research service delivery. NARO will continue operating the Competitive Grant Scheme (CGS) and strategic allocation of core funds to facilitate public- private sector partnerships.

**Subsidiarity:** NARO coordinates a pluralistic NARS; subsidiarity will be key to increasing stakeholder engagement and equity, and to give all constituents a sense of belonging.

**Transparency:** NARO's pursuit for transparency will ensure integrity in all aspects. This will promote professionalism and ethics in agricultural research service delivery. NARO will use established mechanisms for participatory resource allocation, peer review, information sharing and allow open discussion on resource mobilisation ventures.

**Accountability:** NARO promotes the principle of value-for-money in resource allocation, utilisation and reporting among the various actors in agricultural research.

**Excellence:** NARO continues to pursue excellence and design modalities to ensure that pluralism accentuate research processes and outputs. The organisation will ensure that all service providers comply with standards of excellence and will provide a conducive environment for creativity in the frontiers of science.

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## ABBREVIATIONS AND ACRONYMS

<b>ABIZARDI</b>	<b>Abi Zonal Agricultural Research and Development Institute</b>
<b>ARDC</b>	<b>Aquaculture Research and Development Centre</b>
<b>ARTP</b>	<b>Agricultural Research and Training Project</b>
<b>ATAAS</b>	<b>Agribusiness Advisory Services project</b>
<b>ATT</b>	<b>Average Treatment effect on the Treated</b>
<b>BRAC</b>	<b>Bangladesh Rural Advancement Committee</b>
<b>BOU</b>	<b>Bank of Uganda</b>
<b>BUGIZARDI</b>	<b>Buginyanya Zonal Agricultural Research and Development Institute</b>
<b>BUZARDI</b>	<b>Bulindi Zonal Agricultural Research and Development Institute</b>
<b>CBOs</b>	<b>Community Based Organizations</b>
<b>CEDO</b>	<b>Child Rights Empowerment and Development Organization</b>
<b>CGIAR</b>	<b>Consortium of International Agricultural Research Centres</b>
<b>CGS</b>	<b>Competitive Grants Scheme</b>
<b>CP</b>	<b>Commercial Production</b>
<b>EAC</b>	<b>East African Community</b>
<b>FAO</b>	<b>Food and Agriculture Organization</b>
<b>FGD</b>	<b>Focus Group Discussion</b>
<b>FHH</b>	<b>Female Headed Households</b>
<b>FICA</b>	<b>Farm Inputs Care Centre Limited</b>
<b>GDP</b>	<b>Gross Domestic Product</b>
<b>HDDS</b>	<b>Household Dietary Diversity Score</b>
<b>HFCS</b>	<b>Household Food Consumption Score</b>
<b>HFIAS</b>	<b>Household Food Insecurity Access Score</b>
<b>ICM</b>	<b>Information Classification and Management</b>
<b>IE</b>	<b>Impact Evaluation</b>
<b>KAZARDI</b>	<b>Kachwekano Zonal Agricultural Research and Development</b>
<b>IFPRI</b>	<b>International Food Policy Research Institute</b>
<b>KIIs</b>	<b>Key Informant Interviews</b>
<b>MAAIF</b>	<b>Ministry of Agriculture Animal Industry and Fisheries</b>
<b>MHH</b>	<b>Male Headed Households</b>
<b>MoLG</b>	<b>Ministry of Local Government</b>

<b>MSIP</b>	<b>Multi-Stakeholder Innovation Platforms</b>
<b>MT</b>	<b>Metric Tones</b>
<b>MUZARDI</b>	<b>Mukono Zonal Agricultural Research and Development Institute</b>
<b>NAADS</b>	<b>National Agricultural Advisory Services</b>
<b>NaCRRI</b>	<b>National Crops Resources Research Institute</b>
<b>NaFIRRI</b>	<b>National Fisheries Resources Research Institute</b>
<b>NGEZARDI</b>	<b>Ngetta Zonal Agricultural Research and Development Institute</b>
<b>NARO</b>	<b>National Agricultural Research Organization</b>
<b>NAROSEC</b>	<b>National Agricultural Research Organisation Secretariat</b>
<b>NARS</b>	<b>National Agricultural Research System</b>
<b>NGO</b>	<b>Non-Governmental Organization</b>
<b>OWC</b>	<b>Operation Wealth Creation</b>
<b>PARIs</b>	<b>Public Agricultural Research Institutes</b>
<b>PDM</b>	<b>Parish Development Model</b>
<b>PSM</b>	<b>Propensity Score Matching</b>
<b>PWD</b>	<b>People with Disability</b>
<b>SLM</b>	<b>Sustainable Land Management</b>
<b>SP</b>	<b>Subsistence Production</b>
<b>TIMPs</b>	<b>Technologies, Innovations and Practices Management</b>
<b>TORs</b>	<b>Terms of Reference</b>
<b>TTM</b>	<b>Task Team Members</b>
<b>UBOS</b>	<b>Uganda Bureau of Statistics</b>
<b>UGX</b>	<b>Uganda Shillings</b>
<b>UIRI</b>	<b>Uganda Industrial Research Institute</b>
<b>UMI</b>	<b>Uganda Management Institute</b>
<b>ZARDI</b>	<b>Zonal Agricultural Research and Development Institute</b>
<b>URA</b>	<b>Uganda Revenue Authority</b>
<b>USTA</b>	<b>Uganda Seed Traders Association</b>

## FOREWORD

NARO has, over time, invested substantial public resources in the development, dissemination and dissemination of improved technologies, innovations, and management practices (TIMPs) that contributed to improving production and productivity at farm and national levels. The technologies have also contributed to household food security, improved farmer incomes, and alleviated hidden hunger. There is, however, paucity of information on the impacts of these technologies on household incomes, livelihoods, and national economic development. Due to information gaps on technology contribution to household and national welfare, NARO Council explicitly directed management to undertake impact studies regularly to produce data to support evidence-based decision-making function. This impact report, therefore, provides evidence on how NARO through release of improved bean and maize technologies with better traits such as early maturity, pest, and disease tolerance, and better yields, has contributed to improvement livelihoods and Uganda's economy. This impact assessment report was developed by NARO in collaboration with International Food Policy Research Institute and Uganda Management Institute. I sincerely thank the NARO Council for this foresightedness and the team for the report.



Ambrose Agona (PhD),

**DIRECTOR GENERAL, NARO**

## ACKNOWLEDGEMENT

The research team is indebted to farmers in the study areas and the technical and political leadership and key informants who voluntarily provided information for this study. The team further acknowledges NARO Council and NARO management for strategic direction and funding. Special appreciation goes to the technical research team from PARIs and NARO Secretariat who actively participated in the study. The team further thanks Dr. Ambrose Agona-Director General NARO, Dr. Yona Baguma, Deputy Director General NARO, Dr. Anton Bua (Senior Principal Research Officer and Technical Advisor), Dr. Lukwago George (Head PME), Dr. Damalie Akwango-Aliu (Coordinator of the study), Mr. Ariong Richard (Research Analyst), Dr. Isaac Kiyingi (Research Analyst) and Dr. Godfrey Bwanika (Consultant) who fully participated and guided the study.

NARO acknowledges the support from the Government of Uganda, the Ministry of Agriculture, Animal Industry and Fisheries; and Development Partners. The broad support NARO receives to conduct, promote and undertake agricultural research includes but not limited to political, financial, socio-economic, education and training.

## EXECUTIVE SUMMARY

This report presents findings of a countrywide survey conducted to assess the adoption and impact of improved NARO bean and maize technologies on farmers' livelihoods and the national economy. In Uganda, maize and beans are prioritized as strategic commodities to drive improved food and nutritional security and contribute to socio-economic development. NARO has invested substantial resources in developing bean and maize technologies yet the impact of these crops on livelihoods and overall economic development in the country is not well documented. Thus, this study sought to conduct an in-depth analysis of the impact of improved NARO bean and maize varieties on livelihoods and economic development in Uganda to generate information for decision-making among stakeholders.

Specifically, the study focused on the objectives to establish the level of farmer adoption and utilization of NARO released bean and maize technologies in Uganda; determine the impact of NARO bean and maize technologies on productivity, household income and the national economy; establish the impact of NARO bean and maize technologies on household food security; and: evaluate the influence of improved bean and maize technologies in fostering gender equity among households. Data were collected through a cross-sectional household survey of 1445 households, focus group discussions, key informant interviews, and secondary data review. Primary data were collected from six ZARDIs where the sample size was drawn.

Results of the study indicated that 79 percent maize farmers and 60 percent of bean farmers were using improved varieties released by NARO. BUGIZARDI (85%) followed by BUZARDI (76%) and NGETTA (73%) had the highest adoption levels of improved varieties. The popular bean varieties included NABE 15, NABE 17, NAROBAN 1, NAROBAN 2, and NAROBAN 3 and in the case of maize varieties, LONGE 5, LONGE 10, and BAZOOKA stood out. The rate of adoption stood at 33 percent and 45 percent for beans and maize respectively in 2016 and improved to 38 percent and 46 percent in 2020. Evidence shows that drivers of adoption included variety attributes such as better yields, marketability, palatability, access to the seed, public private partnerships along the value chains; and farmer attributes such as access to information and credit.

Overall, about 72 percent of surveyed households had acceptable food consumption status, thus considered food secure. In addition, results show that adopter households were more food secure (76%) compared to nonadopters (63%) based on food consumption grade. This indicates a positive contribution of NARO technologies to food security. The study also showed that beans and maize combined contributed about 43 percent and 53 percent to female and male energy intakes, respectively. Food security of household was influenced by education level, age, and access to credit.

The assessment also shows that use of the improved technologies increased household income by UGX 1,650,000 (36 percent) for bean farmers and UGX 2,083,000 (48 percent) for maize farmers. Additionally, the estimated national economic benefits of adopting improved maize technologies are about US\$ 22 million, US\$ 45, and US\$ 69 at adoption rates of 25 percent, 50 percent, and 75 percent respectively. Similarly, results showed an increase in benefits with increased adoption levels for bean technologies at US\$ 4 million, US\$ 8million and US\$ 13million.

The economic benefits that accrue from improved maize technologies are greater than those for beans due to the larger area under production for maize technologies and a higher adoption rate. These benefits accrue mostly to the producers largely due to an increase in market surplus. The study demonstrates that there are positive economic returns from investment in beans and maize research and technology dissemination programs in Uganda.

There was increased involvement in decision-making regarding production resources among men and women within adopters. Overall, credit access was higher in adoption areas compared to non-adoption areas with FHH accessing more credit (43%) compared to MHH (38%) in adoption areas. There was a reduction in workload among adopters.

The technologies significantly increased beans and maize production and productivity thus increasing household income and food security. At a macro-level, this has led to an increase in Uganda's annual maize and bean exports. The results also revealed that the returns to investment in developing and disseminating maize and bean technologies are positive and significant.

The study recommends further concerted efforts and resource allocation in the areas of extension, research, and access to finance, access to information on TIMPs, seed availability and technology dissemination strategies for better impact.

# 1. INTRODUCTION

## 1.1. Background

Since her inception, NARO has developed and disseminated improved crop varieties of over 17 staple and non-staple crops that are better yielding, climate adaptive and with consumer-preferred qualities. The breeding programmes have focused on variety development with traits such as early maturity, drought tolerance, pest and disease resistance, reduced cooking time, higher yields, and nutrient-enrichment. In the national development plans (NDP), government has consistently prioritized beans and maize as strategic commodities to contribute to improvement of household incomes and food security.

Globally, beans are the most important legumes, estimated to be the second and third important sources of dietary protein and dietary energy respectively (CASA, 2020). In the last decade, NARO beans programme has developed varieties that are; resistant to multiple biotic and abiotic stresses such as pest and diseases, suitability to different agro ecologies, and efficient resource use to deliver high yields with micronutrients to tackle hidden hunger. Additionally, the breeding objective has considered consumer preferences for various market classes of beans. To-date a total of 16 market-class bean varieties have been developed with better array of traits compared to the older varieties. For instance, the new varieties have a yield (approx. 1.6 MT/ha) which 15-65% higher compared to traditional varieties (Nkalubo, 2020). Among the new bean varieties is a set of bio-fortified varieties with enhanced levels of iron and zinc micronutrients. The bio-fortified varieties are a source of micronutrients to resource-poor households in communities where women of reproductive age and children are vulnerable to undernourishment. In 2018, national bean production was estimated at over 940,000 MT produced from more than 696,000 ha (UBOS, 2019). Productivity of beans also increased from 0.7 MT/ha in 2012 to slightly over 1.2 MT/ha in 2018. Formal exports of beans have increased from about 40000 MT in 2014 to 257000 MT in 2018, raking in about USD 93 million per year in foreign earnings (UBOS, 2019 and BOU, 2019). Also under the maize program, strides have been made with the release of 26 biotic stress-resilient varieties to address different production constraints in low and mid altitude and highland areas of Uganda. The released maize varieties yield 7 to 9 MT/ha compared to older varieties that yield less than 4 MT/ha. Area under maize acreage has increased from 1.1 million ha in 2014 to 1.2 million ha in 2018. The corresponding increases in production were 2.8 million MT and 4 million MT with an average annual export earning of USD 111.3 million (BOU, 2019). Similarly, productivity of maize production has increased from 2.5 MT to 3.4 MT per hectare (UBOS, 2019).

Investments in breeding and development of bean and maize varieties have improved the country's seed industry. The seed sector growth is attributed to improvement in quality seed production with NARO's support through routine technical monitoring and backstopping of seed actors in collaboration with the seed certification department of MAAIF. Currently, more than 10 seed companies are licensed to commercialize production of certified bean seed and about 30 are involved

in commercial production of certified maize seed varieties. The formal seed sales increased to 14342 MT (with 45% hybrid seed) from 1144 MT (27% hybrid seed) in 2014.

The above background demonstrates that the substantial investment by government and development partners in the development of bean and maize technologies in the last 10 years and under the national development planning is bearing fruit. Further investment is planned given the two commodities are under the government set of priority commodities in the medium term. However, the impact of these crops on livelihoods and overall economic development in the country is not well documented. Thus, this study was conducted to generate evidence on the impact of NARO bean and maize technologies on household livelihoods and Uganda's economy. The evidence herein is aimed to inform decision making on agricultural research and investment by Government of Uganda in the medium to long term.

## 1.2. Description of interventions

Despite the economic importance of beans and maize to the livelihoods of millions of households in Uganda, on-farm yields have remained low, compared to the potential yield of especially improved varieties which have significantly higher performance compared to the landraces and obsolete varieties. The low productivity has been attributed to limited access to quality seed, poor crop management practices, low adoption of productivity-enhancing technologies, emerging and recurring pests and diseases, bouts of unpredictable drought, drudgery, and poor post-harvest handling practices (CASA, 2020). Other challenges along the value chains include limited efforts for value-addition, lack of streamlined commodity aggregation and marketing, inadequate extension and limited information on available technologies, lack of effective coordination and collaboration of key value-chain players, inadequate capacity for quality assurance of seed in the seed system and commodity value chains, and weak research-extension-farmer linkages. Despite the challenges, output has continued to grow implying that area under production has increased and adoption of improved varieties has made inroads. Whilst efforts are being made to increase use of improved seed and productivity enhancing technologies, many farmers are often inclined to planting older varieties where seed recycling has become a norm (Masinde, 2019).

To address challenges that have undercut production, productivity, and profitability of the bean and maize enterprises, NARO through various frameworks (e.g., NARO 10-year strategic plan, NDP2, ASSP), refocused on interventions aimed to continuously develop human and infrastructural capacity for research and technology development and promotion in line with the global trends in breeding approach. Scientists were trained and retooled in modern research methods and breeding skills; research facilities such as screen-houses, fields and laboratories were established and rehabilitated. Demand-led research to develop varieties suitable for farmers and value chain actor needs have also been embraced by NARO. Variety development was fast-tracked by leveraging on existing global collaborations and networks to access germplasm and shared services such as genotyping and technical backstopping on modern breeding methods. This, in turn, increased breeding efficiency, led to faster variety release, and improved variety turnover. The technology development programmes also ensured that new technologies are gender responsive.

Through these efforts, 16 farmer-preferred, market-oriented bean varieties were developed and officially released (Nkalubo et al, 2010; 2018). The improved bean cultivars are of two growth types; bush growth type suited for low (<1000 masl) to mid (1500 masl) altitude agro-ecologies and climber growth type suited for mid (1500 masl) to high (>1500 masl) altitude agro-ecologies. The bean varieties have several desirable attributes, including high yields (up to 3300 kg $ha^{-1}$  for bush and 4500 kg $ha^{-1}$  for climbers), drought tolerance (NAROBAN 6 & NAROBAN 7), pest and disease resistance, early maturity (series of NABE 15 to NABE 19, and NAROBAN 1 to NAROBAN 3), higher iron and zinc micronutrient content (series of NAROBAN 1 to NAROBAN 7) and all these varieties have market and consumer preferred traits (in terms of grain colour, grain size, cooking time, and taste).

In the case of maize, a total of 26 high yielding, stress-tolerant maize varieties were released and commercialized in the period 2010 to 2020. The released varieties are stable and adapted to mid- altitude areas (800 to 1400 masl) and highland areas (1500 to 2400 masl). They have a good level of resistance to major biotic challenges such as diseases like leaf blight, grey leaf spot, maize streak virus, and ear rot; and storage pests such as weevils. With production under good practices, farmer yields of hybrid varieties can reach up to 9 tons per hectare. NARO also improved and released an open- pollinated variety (OPV), LONGE 5D which has turned to be a good performer and popular among farmers. Initially, the LONGE 5D variety was bred for enhanced protein content (quality protein maize-QPM) but was later improved for better agronomic qualities and disease resistance. Besides, LONGE 10H (hybrid) variety is very common among maize farmers in Uganda with an estimated market share of 30 percent. Recent varieties such as UH5354 (Bazooka) and NAROMAIZE 56 are particularly tolerant to maize lethal necrosis (MLN), which is a new maize disease in the East African region. Other varieties include three imazapyr resistant (IR) varieties for the management of striga and two highland-adapted disease-resistant and early maturing varieties with a potential yield of 10 to 12 ton $ha^{-1}$ (MAAIF, 2019).

To ensure continuous flow of quality improved bean and maize varieties into the seed system, NARO has maintained consistent support to the seed actors by producing and supplying Early Generation Seed (EGS), training local seed businesses; and seed companies which in turn have facilitated growth of Uganda's seed industry. Currently, there are over 30 seed companies operating in Uganda (e.g., Victoria seeds, NASECO seeds, FICA seeds, Pearl seeds, Equator seeds, Masindi seed, and East Africa seeds). Community Based Organisations, NGOs and farmer groups involved in production and supply of basic/foundation, certified and quality declared seed (QDS) have also been strengthened and trained on good practices. In the period 2015 to 2020, NARO produced 96 MT of breeder bean seed and 492 MT of foundation bean seed while under cereals programme, 2.7 MT of breeder maize seed and 12.55 MT of foundation seed was produced and, all was disseminated through seed companies, NGOs, and farmer local seed businesses.

To improve on uptake of the several technologies by farmers and other value chain actors, NARO intensified sensitizations, training, and demonstrations to showcase best-bet technologies through participation in agricultural shows/exhibitions and support to multi stakeholder innovation platforms (MSIPs). This led to increased awareness of NARO technologies. These efforts have been supported

by collaborations with partners such as CGIARs centres (CIAT/PABRA and CYMMT), CBOs, seed companies, farmer groups, NGOs, and other stakeholders.

Additionally, commodity innovation platforms have been created to support several functions namely training and interactions among various actors to enhance seed and grain demand for new varieties and feedback to inform future variety deployment. In addition, the platforms have provided space to farmers, agricultural service providers, researchers, the private sector, and other stakeholders to jointly identify, analyse and alleviate challenges and constraints to adoption and commercialization of new varieties. The innovation platforms established include the National maize and bean innovation platforms of MAAIF, the Greater Masaka bean innovation platform, Kyazanga bean innovation platform, Shema bean innovation platform, Soroti bean innovation platform, Lwengo bean innovation platform, among others. The platforms focus on increasing access to quality seed, information dissemination, enhancing the use of complementary production inputs, fostering supply of quality seed and grain, and promoting collective marketing. Through these platforms, NARO has implemented continuous learning and innovation process to enhance utilisation of bean and maize production technologies through the value chain systems approach. This value chain approach has reduced bottlenecks to production, supported access to quality seed, and improved producer-buyer market linkages.

To address gender inequalities, NARO has mainstreamed gender in her research and development interventions. NARO has used a gender transformative intervention approach where technologies that reduce drudgery in production and postharvest handling have been generated, such as planters and threshers. The use of herbicides is also promoted to help farmers reduce costs related to land preparation and weeding. However, access to these technologies is still a challenge for a wider net of farmers. A gender-responsive seed credit model and contract seed production has been popularized and to increase access to seed especially among bean producers. Inclusive collective marketing and aggregation model, to increase access to markets and farmer income has also been promoted. NARO has partnered with Master card to promote financial linkages between farmer groups and agriculturally based financial digital platforms that enable access to credit at low interest rates, and direct payments to mobile money account of producer farmers. This initiative has supported access to agribusiness credit and financial independence among the youth and women in bean production and resulted in their improved ability to acquire assets to foster gender equity (Aripong et al., 2018).

### 1.3. Objectives of the Study

Overall objective of the study

The aim of this study was to assess the impacts of improved NARO bean and maize technologies on household food security, income, and Uganda's economy.

Specific objectives

The specific objectives of the study are to:

1. Establish the level of farmer adoption and utilization of NARO released bean and maize technologies in Uganda

2. Determine the impact of NARO bean and maize technologies on productivity, household income, and consumer surplus to the economy
3. Establish the impact of NARO bean and maize technologies on household food security
4. Evaluate the influence of improved bean and maize technologies in fostering gender equity among households.

### Research questions

**Objective 1: Establishment of farmer adoption and utilization of NARO improved bean and maize technologies in Uganda, the following research questions were examined:**

- 1) What is the level of farmer adoption of NARO improved bean and maize technologies?
- 2) What are the mechanisms used to access improved bean and maize technologies?
- 3) What are the key approaches used to access improved bean and maize technologies by users?
- 4) What are the factors influencing adoption of NARO improved varieties?
- 5) What dissemination pathway contributed most to farmer adoption of improved technologies?

**Objective 2: Determine impact of NARO bean and maize technologies on productivity, household income, and consumer surplus:**

- 1) What is the change in production and productivity due to adoption of NARO improved bean and maize varieties?
- 2) What is the change in household income due to adoption of improved maize and bean varieties?
- 3) What is the contribution of NARO maize and bean technologies to economic development?

**Objective 3: To establish the impact of improved NARO bean and maize technologies on household food security:**

- 1) What is the role of NARO improved bean and maize technologies in household food security?
- 2) To what extent has the household food security improved due to the adoption of improved NARO bean and maize technologies?
- 3) What is the contribution of bean and maize consumption to dietary energy of household consumers?

**Objective 4: To determine the role of improved bean and maize technologies in fostering gender equity among rural households:**

- 1) How have the bean and maize technology interventions improved women's and youth access to and control of resources including factors of production?
- 2) How have the maize and bean interventions changed women's workload and well-being?
- 3) To what extent have the bean and maize technology interventions enhanced women's decision-making abilities and at household level?
- 4) To what extent have the beans and maize technology interventions enhanced employment of women and youth along the bean/maize value chains?

### 1.3 Rationale

Government has supported agricultural research and development (R&D) through MAAIF and NARO, leading to the development of several technologies that have a potential to improve agricultural productivity in Uganda. Despite the many interventions in R&D, there is still a paucity of information on the current adoption levels, household incomes, food security and nutrition, and contribution of NARO technologies to national economy. Limited information on benefits of interventions can cast doubt on justification for more funding to implement additional investments in R&D. However, additional investment is central to Uganda's development especially at a time when government focus is to spur agro-industrialization to foster agricultural transformation and long-term national aspiration to economic development from a low income to a high-income country. This study was, therefore, conceived to inform government and stakeholders in policy formulation and decision making for the agricultural sector on impacts of agricultural technologies that NARO has generated over the past years.

### 1.4 Structure of the report

The report proceeds with section (2), which highlights the methodology used in the study; defines key concepts, outcome and explanatory variables and; provides the challenges faced while conducting the study and the limits of this study. This is followed by section (3), where findings of the study are presented. In section (4) conclusions of the study are presented and recommendations suggested.

## 2. METHODOLOGY

This section presents geographical scope of the study area, sample size, sampling techniques, the research approaches, methods, and materials used in data collection and analysis. It also explains measurement approaches for the various outcome variables namely adoption, yield, income, and food security, gender, and national economic benefits. Additionally, limitations and challenges of this study are presented.

### 2.1 Study area

The study was conducted in six out of nine research agro-ecologies namely, Abi and Ngetta located in the Northern region, Buginyanya in Eastern region, Bulindi and Kachwekano zones in Western region, and Mukono zone in Central region (Fig. 1). Districts found in each zonal agricultural research area are defined in Annex 1.



Figure 1: Location of data sources

## 2.2 Evaluation design and data

An evaluation approach was adopted, which was in line with the reconstructed intervention logic of the NARO research program (theory of change). The intervention logic demonstrates the causal pathways from research outputs to outcomes and impact on intended beneficiaries. It considers the main changes that occurred during and beyond the intervention. The logic assumes that improved technologies if adopted by farmers lead to increased production and productivity; which eventually contribute to increased household incomes, better food access, and nutrition security; and ultimately, improved beneficiaries' livelihood standard, largely driven by increases in incomes and consumption (of necessary food and non-food items). Ultimately this would be reflected in improved national economic welfare aggregate indicators. The evaluation used a comparative approach (of the technology adopters/ treatment household vs non-adopters/control households) to estimate and infer impact of interventions on selected outcomes (income, food and nutritional security, production, productivity, gender equity and national economic benefits). The treatment households were defined by use/adoption of NARO improved varieties (for the period 2016 - 2020) while the untreated were households that were not using the improved technologies.

The data used were collected following a mixed methods approach, to have relevant quantitative and qualitative data for this study. Concurrent collection of both qualitative and quantitative data was adopted because of the time constraint.

Cross-sectional data mostly of quantitative nature were collected following a semi-structured questionnaire developed, reviewed, and pretested before use during the survey. Trained enumerators through personal interviews administered the questionnaire. The questionnaire was adapted in the XLS form computer programme to facilitate data collection based on computer assisted personal interviews (CAPI). Survey CTO application was used for digital data collection using tablets. The questionnaire was aligned to the study objective to ensure that it addressed all the research evaluation areas including technology adoption, farmer production and productivity, household income, household assets, food and nutritional security, social capital, and gender empowerment. Respondents were also asked about the source(s) of their improved bean and maize technologies.

The qualitative approach was incorporated in the study to enrich the evaluation results and gain deeper understanding of results obtained from the quantitative data by shedding light on the processes and causal relationships. It was also used to collect data on areas that could not be captured by quantitative approach e.g., reasons for negative or positive impact, and intended or unintended impacts. Qualitative data collection employed a combination of participatory techniques such as Focus Group Discussions (FGDs), key informant interviews (KIIs), physical observations, photography, and video recording. Secondary data were collected through desk reviews of relevant literature. Highlights of the relevancies of these approaches are summarised below:

- a) Focus Group Discussion (FGD) guide: FGDs were used to generate information on collective views of the respondents. According to Morgan (1998), focus groups are essential for generating experiences and beliefs of respondents. In addition, Bloor et al, 2001, noted that FGDs can be used to extend, qualify, or challenge data collected by other methods. In

this study, data generated through FGDs were used to triangulate information obtained from adopters and non-adopters of improved NARO bean and maize technologies. A focus group discussion guide was developed and reviewed to ensure alignment to evaluation questions.

- b) **Field Observation and Video Recording checklist:** To gain additional insight on the characteristics of adopters and non-adopters, field observations and video recording checklists were developed and used for the study. These two methods were used in the analysis of agronomic/crop management practices of respondents in relation to the NARO's recommended standard practices for beans and maize. Video recording captured visual information right from the farmer fields to the markets. The information was used to produce a documentary on the impact of improved NARO beans and maize technologies on the livelihood of the farmers, citing cases.
- c) **Desk review of literature:** Review of relevant literature and secondary information related to the study was carried out. Secondary information generated included baseline figures of production/productivity of bean and maize varieties, and; existing evidence of impact of improved NARO bean and maize technologies. The information was obtained by reviewing documents and databases such as: bean and maize research project documents at PARIs, Agricultural Technology and Agribusiness Advisory Services (ATAAS) project reports, Agricultural Research and Training Project (ARTP) reports, NARO Annual Performance Reports, NARO databases, Uganda Bureau of Statistics (UBOS), Uganda Revenue Authority (URA), Food and Agricultural Organization of the United Nations (FAO) and other studies on beans and maize in Uganda.
- d) **Checklist for key informants:** Key informant interviews were also conducted with officials from relevant organizations at National, District and Community levels. The organizations from which key informants were selected included Bank of Uganda, Ministry of Trade, Seed Companies, Uganda National Bureau of Standards, MAAIF, URA, UBOS, NARO Secretariat, National Crops Resources Research Institute, Integrated Seed Sector Development (ISSD) and Local Government agricultural departments (District/Sub-County). Key Informant interview checklists were developed for each category of key informants based on study objectives.

## 2.2 Sampling and sample size

Thirty districts from six agro-ecological zones (located in all the four regions of Uganda) were purposively selected for the study as key maize and bean growing areas. Based on the size of the NARO zone, sample districts were selected as key bean and maize growing districts. For each selected district, one sub-county whose farmers largely grew beans and maize was selected as treatment and one sub-county was selected as a control. The treatment sub-counties are those where NARO and her implementing partners actively conducted bean and or maize technology development/ dissemination activities while a control sub-county was that where such intervention did not take place. However, this was merely a guide to sampling because there was no barrier to technology flow from the intervention to non-intervention sub counties. The agricultural departments of the respective

districts/sub-counties provided a list of two categories of households, that is, participants and non- participants. Households categorized as participants were those that were involved in the improved NARO beans and maize technology development and/ or dissemination by NARO and/ or her implementing partners. The non-participants were households that were not involved in any of these interventions. The unit of sampling was a household.

Adopters were households that picked up the technologies and used them for production while non- adopters are households who neither picked nor used the technologies. The participant list had only adopters, implying that all the households that were involved in NARO bean and maize technology intervention adopted the respective technologies. The non-participant category list was sub-divided into adopters and non-adopters. Adopters falling under non-participant group are those who picked up the technology through association/interaction with the participants, a process called spill-over. Thus, for analysis, households categorized as adopters were selected from both the participant and non-participant lists, while the non-adopters were purely non-user of the disseminated technologies. Households that adopted the NARO bean and or maize technologies were randomly formed from the participant and nonparticipant categories of farmers. The non-adopters were few and, all households provided in the list were considered.

To derive the sample size, standard power calculations were performed based on Cochran's (1977) formula expressed below.

$$n = \frac{\left[ \left( \frac{z^2 pq}{e^2} \right) * Dff \right]}{R} = \frac{\left[ \left( \frac{1.96^2 (0.5)(0.5)}{0.03^2} \right) * 2 \right]}{0.93} = 2,294$$

Where:  $n$  is the sample size;  $z$  denotes the statistical certainty (critical value) selected at 95 percent confidence level;  $p$  is the probability of adopting improved NARO bean and maize technologies;  $q$  is the probability of not adopting improved NARO bean and maize technologies;  $e$  means the value of permissible error selected at 0.03;  $Dff$  is the design effect; and  $R$  is the response rate taken at 93 percent.

At standard error level of  $\alpha=0.05$ ,  $\beta=0.2$ , and equal sized treatment and control groups were considered in the sample size calculation, and from the baseline data deriving a 2 per cent effect size and standard deviation (GEL 200) and mean of household income (GEL 1142), a sample size of approximately 2,294 households was obtained, with 1,147 in the treatment group and 1,147 households in the control group. A total of 1,445 households representing 65% of the sample size responded to the study. Actual sample size was affected by funds and the fact that many households considered to be non-participants also fell in the adopter category of farmers.

Table 1 presents the distribution of the surveyed respondents in the agro-ecological zones. The list of districts sampled per zone is presented in Annex 2.

**Table 1: Sample size distribution**

ZARDI	Number of districts	Observations			Proportion
		Nonadopters (Na.)	Adopters (Ad.)	Overall (n)	
ABIZARDI	4	99	100	199	0.137
BUGIZARDI	6	51	283	334	0.231
BUZARDI	4	25	80	105	0.073
KARZARDI	4	73	29	102	0.071
MUZARDI	7	134	362	496	0.343
NGETTA	5	56	153	209	0.145
TOTALS	30	438	1007	1445	1.000

## 2.3 Analysis methods

### 2.3.1. Adoption of improved technologies

#### Level and rate of adoption of improved technologies

Level of adoption was measured by using: (i) the number of households applying the improved technologies and expressed as a proportion/ percentage of households who applied the improved technologies in the past five years to total number of households examined each year; (ii) the percentage of land area under improved technology was also a measure of adoption and in reference to the rate/intensity of adoption. Rate of adoption was expressed as a proportion of arable land that was planted with improved seed to total arable land accessed by the household.

#### Farmer yield

Farmer yield is the crop yield measured as amount of a crop produced, or product such as grain harvested, per unit area of land. Yield is an indicator of intensity of farming, the higher farmland intensity, the higher farm yield, productivity, and profitability.

#### Determining drivers of adoption

Factors influencing technology adoption were determined using a Logit regression model. The model is grounded in the Lancaster theory where it is assumed that the individual choice for a good/service is based on the rational of utility associated with attributes of the good/service in case.

$$prob(y = 1|x) = \frac{e^{\beta x}}{1 + e^{\beta x}}$$

Where the probability for a farmer to have a choice/ adoption outcome ( $y = 1$ ) for a technology is dependent on a set of explanatory factors ( $x$ ) with  $\beta$  being a set of coefficients attributed to each selected explanatory variable.

### 2.3.2 Household Food Security

Food security exists when people, always, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). Whilst there are several methods used to measure household food security (Coates, Swindale, & Bilinsky, 2007), this study adopted the Household Food Consumption Score (HFCS) and its associated Household Dietary Diversity Score (HDDS) to understand food consumption grades and infer on quality of food consumed; and the perception-based Household Food Insecurity Access scale (HFIAS) selected to understand the household access to food. These approaches not only account for the budget and time constraints but also yield reliable indicators of the food and nutrition security situation in a population of interest.

#### Household diet diversity and food consumption

Robust measurement of household food security involves capturing caloric and nutritional intake through anthropometric measurements, multi-visit household expenditures or dietary recall logs within a specified period (Jones et al. (2013)). One of the proxy indicators of household food security is determined using Household Diet Diversity (HDD). HDD measures nutrition component and the economic ability of households to access food groups that meet the nutrition needs of household members usually for a specific period.

To compute HDD data on food consumed were collected using a single visit dietary seven-day recall. The HDD comprises number of different food types/groups (diet diversity) and frequency of consuming the various food types (food frequency) (FAO, 2010; Wiesmann et al., 2009). Subsequently, Food Consumption Grades (FCG) were derived from diet diversity/Food Consumption Scores (FCS) and food frequency as an indicator of food security. FCS generated from household dietary diversity is a qualitative measure of food consumption that reflects household access to food variety and is a proxy indicator for nutrient adequacy of the household members.

#### Dietary energy intake

The quantity of beans and maize consumed per meal and the number of days the same was consumed in a week were captured to guide estimation of per capita consumption and caloric contribution of beans and maize to household diets. To estimate the contribution of beans and maize to dietary energy intake, annual per capita consumption of both beans and maize was estimated based on WHO recommended amount of energy intake per adult individual. The contribution of beans and maize was estimated as a proportion in relation to the daily WHO required energy intake for female and male individuals to live a normal life. To arrive at energy contributions of beans and maize to daily dietary energy requirement, quantities consumed by the sum of household members per day and weekly frequency of consumption were captured in the data collection tool. Also, in the case of beans, the amount consumed was captured in dry form, and after cooking, the amount increases by a ratio of 1:3, leading to three servings.

### Household food insecurity access scale

Food insecurity leads to a situation of having limited or uncertain access to enough food for household members to live an active and healthy lives (Bovell et al., 2015). Households that experience low food security tend to adjust the food quality, variety, or desirability, and at times a reduction in food intake (Coates, Swindale, & Bilinsky, 2007). For this reason, Household Food Insecurity (HFI) was also corroborated using the HFIAS (Household Food Insecurity Access Scale) approach which depicts perception and occurrence of HFI in a gradient which begins with the uncertainty and concern about accessing food followed by adjustments in the family budget on food spending, and then reduces food quality and variety. As food insecurity progresses further, adjustments are made that begin to affect not only the quality and variety but also the quantity of food consumed thus, food portions are reduced, and some meals are omitted. In the next stage where food insecurity becomes more severe, hunger is experienced, initially appearing in adults and finally affecting children. It is within this framework that a set of nine to fifteen questions are usually asked regarding the level of concern and the lack of access to, variety and/or quantity of food. The questions are retrospectively asked about a period between 4 to 12 weeks, and they reflect three different domains of food insecurity namely anxiety and uncertainty about household food supplies; insufficient food quality; and inadequate food intake and the physical consequences to household members (Coates et al., 2007). For each question, the frequency of occurrence (few times, sometimes, & frequently) of the condition in question was captured contingent on an affirmative response on if the condition occurred or otherwise. The HFIAS module gives information on food insecurity (access) at household level (Coates et al., 2007).

Based on the above framework, HFIAS scores were generated. The HFIAS scores are integer form (ranging from 0 to 27), which measures the degree of food insecurity and in this context, household food access was observed for a period of the past four weeks. The HFIAS score variable was calculated for each household by summing the codes for each frequency-of-occurrence question. Measuring Household food insecurity using the HFIAS gives scores between 0 to 27, of which 0 is for a fully food secure household and 27 for a fully food insecure household.

### Prevalence of household food insecurity

From the HFIAS, household food insecurity access prevalence (HFIAP) indicator was derived to provide household categorization into four levels of household food security/insecurity namely food secure, mildly food insecure, moderately food insecure, and severely food insecure. Households become increasingly food insecure as they respond affirmatively to more severe conditions and/or experience those conditions more frequently (Coates et al., 2007). The levels of HFIAP were generated to give an indication of the food security/insecurity situation in the study population as outlined below:

- 1) A food secure household experiences none of the food insecurity (access) conditions, or may just worry, but rarely.
- 2) A mildly food insecure (access) household worries about not having enough food sometimes or often, and/or is unable to eat preferred foods, and/or eats a more monotonous diet than desired and/or some foods considered undesirable, but only rarely whilst not cutting back on

quantity nor experiencing any of three most severe conditions (running out of food, going to bed hungry, or going entire day and night without eating).

- 3) A moderately food insecure household sacrifices quality more frequently, by eating a monotonous diet or undesirable foods sometimes or often, and/or has started to cut back on quantity by reducing the size of meals or number of meals, rarely or sometimes. However, it does not experience any of the three most severe conditions.
- 4) A severely food insecure household tends to cut back on meal size or number of meals often, and/or experiences any of the three most severe conditions (running out of food, going to bed hungry, or going an entire day and night without eating food), and the conditions tend to be frequent. In other words, any household that experience one of these three conditions even once in the last four weeks (30 days) is considered severely food insecure.

#### Determinants of food security

Generalized Linear Model (GLM) was used to determine the factors that drive the household food security outcome, with proportion of HFIAS as the dependent variable. The model assumes a relationship between observations  $y$  of the random response outcome variable  $Y$  and a probability (density) function (O’Laughlin, 1999). GLM supports the development of a strategy for approaching statistical problems that involve non-normally distributed data, in a way that retains much of the simplicity of linear models. The model uses the assumption of exchangeability in that if  $Y$  is the dependent variable,  $X$ s are explanatory variables. In the family of GLM, the Poisson regression model with zero inflation was adopted using HFIAS score as the dependent variable.

#### 2.3.3. Household income

Household income was determined by obtaining the sum of farm income and nonfarm income. All income was computed on a yearly basis (2020 and 2016).

##### Farm income

Farm income was measured by computing the sum of income from all farming activities including crop and livestock income. Crop income was estimated by summing income from bean sales, maize sales, and income from sales of other crops. Livestock income was also estimated by summing income from livestock sales and income from sell of livestock products such as milk, eggs, hides/skins, and meat for the month of production of the said livestock products.

##### Nonfarm income

Nonfarm income is income from activities other than farming namely small trading business, transport business, brick making, and remittances among others. The amounts of income earned were determined through inquiry on frequency for which an earning was got in a year and average amount per time of earning.

participants and  $Y_{0i}$  outcomes for non-participation scenario. Since the counterfactual,  $E(Y_0|J = 1, X)$ , is not observable in the data, the average outcome in the control group,  $E(Y_0|J = 0, X)$ , is used to estimate it – then considered a counterfactual.

The counterfactual was generated using PSM approach where a farmer in the non-treatment group (with a lower sample size) was matched with a counterpart in the treatment group to create two groups of farmers that are comparable in terms of sex, age, farming experience, education, marital status of household head, household size, access to credit, group membership of a household member, and agro-ecological zone, in other words adopters and non-adopters need have the same or close in a set of factors that characterise them such as age, sex, farming experience, education among others that influence adoption and impact on the outcome variables of interest. Matching was done using Nearest neighbour (NN), Kernel, and the Radius matching approaches.

### Switching regression

PSM is a useful tool for impact evaluation when only observed characteristics are believed to affect program participation. However, the effect of unobservable factors may confound the effect. The study therefore checked robustness of results under different assumptions, using an endogenous switching regression. Following Maddala & Nelson (1975) and Ravallion (2003), the switching regression can be defined by the following expressions (Eq. 1 – 3).

$$S_i^* = Z_i\gamma + u_i \quad (1)$$

$$J = \begin{cases} 1 & \text{if } S_h^* > 0 \\ 0 & \text{if } S_h^* \leq 0 \end{cases}$$

$$Y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \text{ if } J_i = 1 \quad (2)$$

$$Y_{0i} = X_{0i}\beta_0 + \varepsilon_{0i} \text{ if } J_i = 0 \quad (3)$$

The average treatment effect on the treated/adopters (ATT) is calculated as:

$$E(Y_{1i}|x_{1i}, J_i = 1) - E(Y_{0i}|x_{1i}, J_i = 1) = X_{1i}(\beta_1 - \beta_0) + (\sigma_{\varepsilon_{1i}} - \sigma_{\varepsilon_{0i}})\lambda_{1i} \quad (4)$$

Where:  $Y_{1i}$  is household outcome measure (yield, crop and household income, food security, daily calorie acquisition per capita) for participants in adoption of improved bean and maize technologies and  $Y_{0i}$  for non-participants;  $X_{1i}$  and  $X_{0i}$  are vectors of exogenous explanatory variables relevant to each group. The explanatory variables included in the Logit model should be closely related to participation in the intervention, but they should not be affected by the intervention (Barraud, 2009).  $\beta_1$ ,  $\beta_0$ , and  $\gamma$  are parameter vectors;  $S_i^*$  is the latent variable determining the group that applies the promoted technology; and  $X_i$  is a vector of explanatory variables assumed to explain the probability of participation in the adoption scenario. Equation (1) is a selection equation determining which regime applies while Equations (2) and (3) describes the conditional expectation of the outcome variables in each of the two regimes.

### 2.3.4 Economic evaluation

#### Economic valuation of technology benefits and costs

##### *(a) Sources of data*

Data and information used in the analysis of NPV, IRR, CBR and Economic surplus were gathered from primary and secondary sources in Uganda. Primary data on yield, production costs and farm-gate prices of beans and maize from 2016 to 2020 were obtained from quantitative data of this study. The aggregated data for national production, acreage, exports and local consumption of beans and maize from 2016 to 2020 were obtained from UBOS and BOU databases.

Labour is a major component of production costs. Estimation of annual labour input in bean and maize production was obtained from the primary data collected through household interviews and FGDs. Data were collected on amount of labour spent on one acre of beans and/or maize in one season. These data enabled assembly of production costs for the periods of 2016, 2017, 2018, 2019 and 2020 (Annex 15). The other production costs such as seed, pesticides, fertilizers, herbicides, and post-harvest handling equipment were also included in benefit-cost analysis but considered as a non-traded good. This required no adjustments (with conversion factor) given the liberal economic environment in which commodity exchange operated. The cost of land was not included in the analysis, as land is never depreciated. Therefore, no cost opportunity was attached to land.

The national total production ( $Q$ ) and area (acres) under beans and maize were accessed from UBOS database. Changes in yield ( $\Delta Y$ ), adoption costs ( $\Delta C$ ), adoption rates ( $t$ ), and annual acreage under improved NARO beans or maize technologies were computed using adoption levels based on the national averages indicated by UBOS.

The Consumer Price Index (CPI) was obtained from Bank of Uganda while the nominal prices of maize and beans were obtained through analysis of the primary data. The inflation effect for price data (2016 to 2020) were deflated by dividing nominal prices by the CPI to obtain real farm gate prices. Consumer price indices were also used to deflate the total project cost and the gross benefits of the projects. The 2016 CPI was used as a base year because the Uganda government considered it a normal year when the economy was stable. This coincided with the period when beans and maize improved technology promotion was at its peak using ATAAS and other NARO projects.

The costs of research and dissemination were available, as secondary data, from reports and budgets of NaCRRI that hosts the legumes and cereals programmes responsible for the bean and maize technology generation, development, and transfer in Uganda. The research costs broadly comprise research and administrative costs of developing technologies while dissemination costs included multiplication, distribution, short-term training and other extension costs.

*(b) Derivation of CBA, IRR and NPV*

The calculation of benefits and costs of NARO's beans and maize research, internal rate of return (IRR) and Net Present Value (NPV) followed the procedure used by Randall (1987), (Masters, 1996) and Gittinger (1982). In undertaking CBA, IRR and NPV analyses, the benefits of research and promotion (dissemination) programs were approximated by the actual net value of production (net of research and promotional/dissemination costs) from improved NARO beans and maize varieties. It was assumed that without improved NARO beans and maize technologies, beans and maize production would have been lower since over 70% of the beans and maize farmers were using improved NARO beans and maize varieties. Both the annual total costs and the annual values of total production (gross benefits) were deflated using the consumer price index to correct for the effects of inflation. The yields used in the analysis were the average farmer yields for the improved beans and maize varieties in kilograms per hectare whereas the area under improved beans and maize production was computed using the annual rates of adoption of improved beans and maize from the national areas under beans and maize production obtained from UBOS database.

Research and promotion (dissemination) expenditures were treated as investments from which the estimated IRR on investment was derived while the returns (incomes) obtained by farmers from improved beans and maize production were treated as the benefit stream. The IRR is the rate realised over the entire period during which costs are incurred and benefits received, in this case from 2016 to 2020. Gittinger (1982) describes IRR as a discounted evaluation measure for a single project or for a set of projects, i.e., the discount rate that makes the net present worth (value) of the incremental net benefit stream equal zero. Indeed, IRR is the maximum interest that a project can pay for the resources used if the project is to recover its investment and operating expenses and still break even (Gittinger, 1982: 480-1). However, IRR does not show whether allocation of resources between investment components, for example (research, adoption, and production) among complementary projects was optimal (Oehmke et al., 1992). Meanwhile, it serves to understand the returns to investment in a crop like beans and/or maize, or to development of single technology like a drought tolerant maize variety.

Only direct expenditures in beans and maize research and promotion were included starting from the initial introduction of breeding crossing lines all the way to release and costs of varietal promotion and dissemination through the variety uptake pathways. Symbolically the calculations of NPV and IRR are as follows:

$$NPV = \sum_{t=1}^5 \left( \frac{\Delta ES_{i,t}}{(1+r)^t} \right) - \sum_{t=1}^5 \left( \frac{C_t}{(1+r)^t} \right)$$

Where, NPV represents Net Present Values;  $\Delta ES$  represents changes in economic surplus;  $r$  is the real discount rate (10% per annum);  $C_t$  represents research and development costs. The annual supply shifts were projected based on adoption of the improved technologies ( $A_t$ ) within the period of impact study (2016–2020) which equates to 5 years.

The aggregate internal rate of return (IRR) was also calculated as the discount rate that equates the aggregate NPV to zero as follows:

$$\sum_{t=1}^5 \left( \frac{\Delta ES_{i,t}}{(1+IRR)^t} \right) - \sum_{t=1}^5 \left( \frac{C_t}{(1+IRR)^t} \right) = 0$$

The investment selection criteria for viable investment should have NPV greater zero (NPV>0) and that with the largest NPV.

### (c) The Economic Surplus Model

The economic surplus (total welfare gains) of NARO bean and maize technologies was calculated using economic surplus framework or production function. This framework uses the principles and formula advanced by Masters (1996), specified as below.

$$WG = KQ - \frac{1}{2} K\Delta Q \quad (1)$$

Where:

$WG$  denotes welfare gains (USD/UGX);  $Q$  is the observed quantity of beans or maize produced; and  $\Delta Q$  represents the change in the equilibrium quantity produced due to the new technology. The change in equilibrium quantity  $\Delta Q = [Q * \epsilon * e * k] / [\epsilon + e]$  represents the vertical shift in supply (change in production costs) estimated as a proportion of the product price,  $K = j / \epsilon - c$ .  $j$  denotes the change in production due to new technology, estimated as a proportion of total production,  $j = [\Delta Y * t] / [Y]$ . Elasticity of supply ( $\epsilon$ ) and demand ( $e$ ). The adoption costs,  $C$  of the new technology estimated as a proportion of the product price,  $C = [\Delta C * t] / [Y * P]$ .

$$WG = [[k * P * Q] \pm \frac{1}{2} [k * P * \Delta Q] \quad (2)$$

$$NWG = WG - E \quad (3)$$

Where:  $E$  is the cost of R&D of research and technology dissemination.

## 2.4 Quality assurance

### Quality of data

To ensure quality, the data collection tools were developed and reviewed by a team of experts from NARO. Enumerators were recruited and trained on the data collection process and the study tools. The enumerators also did mock interviews through role-plays, followed by field pretesting of the tool prior to actual data collection exercise. Data collection was done using the survey CTO application that allowed embedment of constraints to limit spurious data entry. During actual field data collection, ZARDI resident field supervisors provided backstopping. Data were uploaded daily to a designate

NARO CTO server, which allowed central monitoring of data quality and prompt redress to technical issues. Additionally, field experiences during phase-I of data collection in MUZARDI guided tool adjustments for phase-II data collection. Qualitative data were recorded and transcribed for each farmer focus group discussion and Key informant interview.

### Quality of results

Data were downloaded from the central server and analysed using STATA 17. A team of agricultural economists before analysis centrally did data cleaning. NARO scientists did a review of the preliminary results and feedback was used to refine data analysis and presentation in a manner best suited to various target audience.

## 2.5 Ethical conduct and the COVID context

An internal committee comprised of NARO researchers was constituted to review the tool and ensure that data collection falls in line with the national guidelines on research on persons. Also, consent was sought from all respondents visited and all data have been kept secure to keep all private information confidential.

## 2.6 Limitations of the study

This household questionnaire survey inquired about adoption and impact of improved bean and maize varieties developed by NARO and released by MAAIF. In this study, one was considered an adopter if he/she used improved varieties as the case point technologies. Other agricultural practices/ farming methods developed by NARO were merely presented to also present the picture of farmer application of NARO promoted TIMPs. It is also noted that this study is limited only at the farmer level and not the entire commodity value chain.

## 2.7 Challenges

There were two main challenges namely limited funds and delays in data collection due to government instituted restrictions on movement of persons to control spread of COVID-19 pandemic. Due to these challenges, the study took a longer period to be completed than expected. However, considering COVID-19 pandemic, the research team observed SOPs as part of ethical conduct.

The report proceeds with a detailed description of the findings (section 3) presented in line with objectives of the study. The findings are presented per the impact outcome areas, namely, access to information, adoption of NARO technologies and complementary inputs, production and productivity, food security, household income and expenditure, gender dimensions, and contribution to consumer surplus. The report then proceeds with a summary of good practices and a conclusion, which is coupled with recommendations for planning.

## 3. FINDINGS

### 3.1 Introduction

This section is divided into two parts: (1) an overview of demographic and socio-economic characteristics of the respondents and, (2) findings on NARO technology adoption by bean and maize farmers.

#### 3.1.1 General household and household head characteristics

Table 2 highlights general household characteristics as well as characteristics related to the head of household. These characteristics include marital status, education, main occupation, and NARO benefits, among others. The results show that 78 percent of households are male-headed and of who 83 percent are married. Majority (50%) of the households attained primary education. These are closely followed by secondary education at about 29 percent. Thus, 79 percent of famers can be generalized as educated. This is a positive result following government investment in education sector and, yet such an outcome has implications to mind-set change for farmers to appreciate agricultural technologies. Educated farmers tend to be quick to adopt improved technologies, as they are aware of benefits of such technologies (Murage et al, 2015; Mushanje et al. 2010). There was generally no significant difference in education attainment among adopters and non-adopters of NARO maize technologies.

This study identified crop farming as major source of livelihoods by the households (84%) and distantly followed by mixed farming (8%). These results concur with the national report that shows that 80 percent of households are engaged in agriculture (UBOS, 2019). Overall, the patterns of household characteristics were not different across enterprise type (Annex 3).

Seventy three percent of household heads belonged to a group. However, most farmers belonged to a funeral group (about 74%) which is ideally for social support compared to productive association such as seed production group (with 21%), farmer research groups (10%) and savings and credit groups (at about 5%). About 60 percent of households indicated they had benefitted from NARO technologies. Deeper insights of technology are presented in subsequent sub-sections.

Table 2: Household characteristics

Variable	Proportion of farmers		
	Pooled sample (N=1446)	Nonadopters	Adopters
Respondent is household head (%Yes)	0.716	0.701	0.722
Male headed HH	0.783	0.726	0.807
Marital status of HH head			
Divorced	0.033	0.057	0.022
Married	0.830	0.785	0.850
Never married	0.052	0.046	0.055
Widowed	0.085	0.112	0.073
Education level of HH head			
Diploma	0.037	0.034	0.038
No formal education	0.071	0.091	0.062
Nondegree tertiary education	0.035	0.032	0.036
Primary schooling	0.504	0.566	0.478
Secondary schooling "A" level	0.042	0.023	0.051
Secondary schooling "O" level	0.287	0.231	0.311
University level	0.025	0.023	0.026
Main occupation of HH head			
Crop farming	0.842	0.863	0.833
Business	0.017	0.021	0.016
On-farm labour for a wage	0.001	0.000	0.001
Forestry	0.001	0.000	0.001
Formal employment	0.030	0.025	0.033
Livestock farming	0.010	0.009	0.011
Mixed farming	0.076	0.062	0.082
Off-farm labour for a wage	0.004	0.007	0.003
Transporter	0.003	0.002	0.003
Other	0.015	0.011	0.017
HH head belongs to a group	0.732	0.715	0.740
Seed production	0.211	0.211	0.211
Farmer research group	0.096	0.070	0.107
Savings & credit	0.047	0.045	0.048
Funeral	0.739	0.668	0.769
Tree planting	0.094	0.169	0.062
Soil & water conservation	0.007	0.013	0.004
Religious group	0.003	0.000	0.004
Input credit	0.034	0.054	0.026
Others group	0.007	0.006	0.007
Others group	0.074	0.064	0.078
HH benefited NARO technology	0.599	0.370	0.698

### 3.1.2 Household Qualities

This section looks at the household characteristics, which are indicative of the quality of life of the surveyed households. Both majority adopters and non-adopters had houses with burnt stabilized brick as wall material, which is reflective of a good house for human habitation. This is further reflected by quality of floor material, where 52 percent and 43 percent reported concrete floor of their main houses for adopters and non-adopters, respectively. Households with iron roofed houses stood at 86 percent and 78 percent for adopters and non-adopters respectively. These figures were above national averages of 64 percent of iron sheet roofs and 30 percent for brick houses (NAADS, 2015). As a source of energy for cooking, firewood was widely used among households at 86 percent for both adopters and non-adopters (Annex 4). The statistics for house lighting were about 65 percent using electricity, followed by gas lamp at about 13 percent. These sources of energy have implications on natural resource use and environment. Latrine use was at about 57 percent with covered and uncovered latrines at 27 percent, 29 percent respectively. The national latrine coverage is 79 percent (Ssemugabo et al. 2021) and the result presents a picture below the expected in the rural areas. Latrine coverage has implications to household sanitation and public health. Thirty-eight and 50 percent of households owned mobile phones radios respectively (Annex 4). This is of interest since dissemination of technology information through radio and mobile phones is utilised by research and development agencies to deliver messages related to production and markets.

**Table 3: Household qualities**

Variable	Overall (N=1445)	Na.	Ad.	Bean farmer	Maiz e
<b>Building material for walls</b>					
Baked bricks	0.615	0.568	0.635	0.579	0.648
Unbaked bricks	0.096	0.116	0.087	0.096	0.096
Poles & mud/ mad & wattle	0.249	0.288	0.232	0.278	0.222
Grass	0.008	0.007	0.009	0.014	0.003
Cement bricks	0.032	0.021	0.037	0.033	0.031
<b>Building material for roof</b>					
Grass	0.162	0.221	0.136	0.146	0.177
Iron sheets	0.835	0.779	0.860	0.851	0.820
Tiles	0.001	0.000	0.002	0.001	0.001
Asbestos	0.001	0.000	0.002	0.001	0.001
<b>Building material for floor</b>					
Soil	0.410	0.482	0.379	0.408	0.413
Concrete	0.496	0.425	0.526	0.493	0.498
Pressed marram	0.084	0.091	0.081	0.089	0.080
Tiles	0.010	0.002	0.013	0.010	0.009
<b>House lighting</b>					
Candle/wicker lamp	0.010	0.014	0.008	0.016	0.004
Paraffin/hurricane lamp	0.030	0.043	0.025	0.033	0.028
Gas lamp and torch	0.129	0.114	0.135	0.142	0.116
Solar	0.091	0.130	0.073	0.098	0.084
Electricity	0.652	0.648	0.653	0.622	0.681
Biogas	0.087	0.050	0.103	0.089	0.085
Other	0.001	0.000	0.002	0.001	0.001

## 3.2 Access to agricultural information

### 3.2.1 Farmer access to production information

#### Comparison of farmer access to agricultural information

An inquiry was made to understand dynamics on access to information on agricultural practices and technologies applied to maize/bean production in the past five years. The results are presented in Figure 2. Overall results show that 66 percent of the farmers accessed information on agricultural technologies, with adopters at about 74 percent and nonadopters at 49 percent. A comparison of farmers within an enterprise shows that the maize farmers as adopters received more agricultural information (74%) compared to nonadopters (47%). A similar trend is observed among the beans farmers where figures stood at 73 percent and 50 percent.

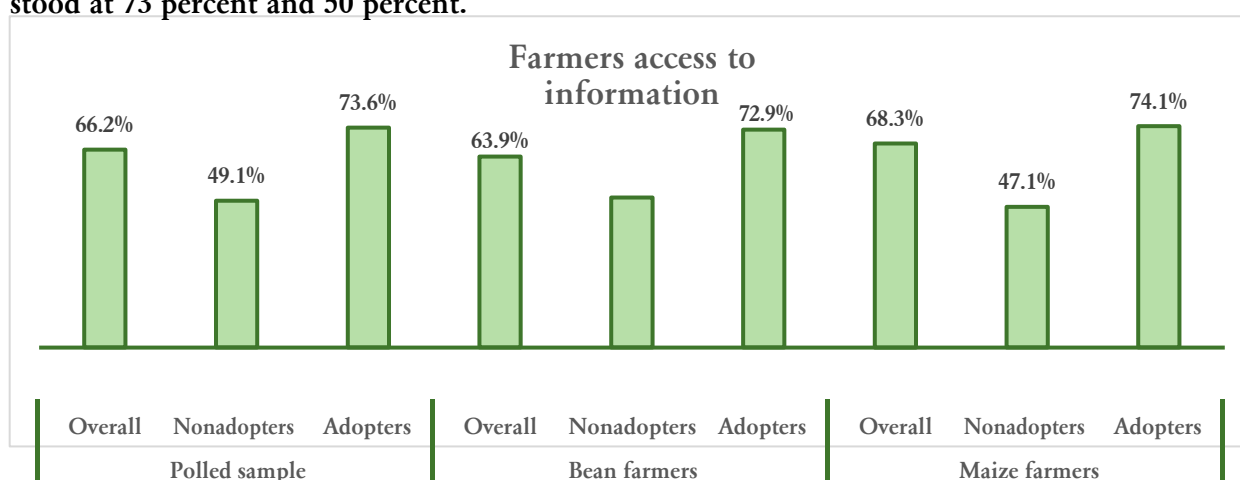


Figure 2: Percent of farmers who accessed agricultural information

Agro-ecological zones are represented by ZARDIs. MUZARDI represents the Lake Victoria Crescent agro-ecological zone (LVCAZ), AbiZARDI for West Nile agro-ecological zone, BUZARDI for Lake Albertine agro-ecological zone, BUGIZARDI for Southeast agro-ecological zone, NGETTA ZARDI for Northern Uganda agro-ecological zone and Kachwekano ZARDI under Southwestern highlands agro-ecological zone. Comparisons of access to information across different agro-ecological zones among adopters and nonadopters is presented in Table 4. Overall BUZARDI had the highest percentage of farmers who received information on agricultural practices and technologies applied to maize/bean production in the past 5 years. The region was followed by MUZARDI and BUGIZARDI zones. The difference in access to information among adopters and nonadopters was significant in AbiZARDI, KAZARDI, MUZARDI and NGETTA. This could be attributed to existence of a strong extension system, seed companies, NGOs, and a network of agro-input dealers within these ZARDIs. Extension system, seed companies, NGOs and agro-input dealers are key mechanisms in distribution of seed. The seed companies and NGOs observed in these regions included World Vision, HODIFA ACDP, NASECO, FICA, Bukoola Chemicals, VEDCO, Elastex, SG2000, and One-Acre Farm. These seed companies access the breeder seed, foundation seed and certified seed who in turn multiply

the seed and sell it to farmers either directly or through agro-input dealers. NARO further has organized farmers into groups to support seed multiplication.

**Table 4: Proportion of respondents who received agricultural information**

ZARDI	Proportion of farmers									
	Pooled sample				Bean farmers		Maize farmers		Men	
	Women	Overall			Na	Ad.	P stat	Na	Ad.	
ABIZARDI	0.543	0.455	0.630	0.000	0.481	0.522	0.426	0.722	0.400	0.579
BUGIZARDI	0.707	0.569	0.731	0.047	0.571	0.759	0.565	0.714	0.708	0.706
BUZARDI	0.771	0.680	0.800	0.014	0.722	0.864	0.571	0.776	0.774	0.770
KAZARDI	0.461	0.370	0.690	0.000	0.370	0.690	-	-	0.308	0.513
MUZARDI	0.736	0.537	0.809	0.000	0.581	0.787	0.483	0.830	0.652	0.761
NGETA	0.569	0.446	0.614	0.002	0.472	0.609	0.400	0.617	0.500	0.581

In the case of Lake Victoria Crescent agro-ecological zone, seed companies like FICA and Bukoola chemicals work with the district agro-input dealers who act as their agents in major towns and trading centres to sell seed and other complementary farm inputs to farmers. These agents were pointed out as major sources of information to farmers thus complimenting the public and private extension systems. More adopters (80.9%) in the LVCAZ accessed agricultural information compared to other zones due to its strategic location and proximity to many actors in the agricultural sector.

In Table 5, it is observed that the most common agricultural information that was accessed by the beans and maize farmers included agronomic practices (56%) and improved varieties (42%) while less than 10 percent received information related to markets, sustainable land use, climate adaptation and weather, yet these elements are critical for better crop performance and eventual adoption of NARO technologies. The evidence shows similar proportions of the different types of agricultural information accessed for bean and maize technology adopters.

**Table 5: Comparison of information access for non-adopters and adopters per enterprise**

TAPs	Proportion of farmers							
	Pooled	Overall		Bean farmers		Maize farmers		
	(N=1445)	Bean	Maize	Na.	Ad.	Na.	Ad.	
Improved variety	0.424	0.415	0.433	0.285	0.501	0.185	0.500	
Seed type	0.143	0.150	0.137	0.132	0.162	0.115	0.143	
Agonomic practices	0.563	0.533	0.593	0.402	0.619	0.420	0.639	
Postharvest practices	0.190	0.178	0.200	0.157	0.193	0.076	0.234	
Market information	0.058	0.061	0.055	0.046	0.071	0.032	0.062	
Sustainable land use	0.066	0.076	0.055	0.043	0.099	0.025	0.064	
Climate adaptation	0.015	0.024	0.005	0.032	0.019	0.000	0.007	
Weather information	0.018	0.021	0.015	0.021	0.021	0.019	0.014	
Other information	0.008	0.013	0.003	0.018	0.009	0.006	0.002	

During the ATAAS project, 2012-2018, NARO in collaboration with the mother ministry implemented several interventions intended for promotion of Conservation Agriculture (CA) for improved crop and livestock yields. Under various ZARDIs, technology packages on CA were introduced via formal practical trainings and demonstrations. The practices include minimum tillage (Permanent Planting Basins (PPBs) and rip lines), use of appropriate application of herbicide types and rates, agro-forestry, mulching and line spacing. There is need to engage with other technology pathways like civil society, CBOs, and NGOs to upscale these technologies to farming communities.

### Sources of information

Access to information by rural farmers is often a challenge and for farmers who get hold of some agricultural information, it is commonly from peer relations. In Table 6, it emerges that majority (58%) of farmers who accessed agricultural information got it from a government sponsored extension agent and 35 percent said they got information from a fellow farmer. Access to agricultural information from government extension agents was more among maize farmers (63%) as compared to bean farmers (53%) and, following *a priori* expectation, bean and maize adopters outperform the nonadopters in accessing information from most of the sources available to both.

**Table 6: Sources of information**

Info source	Proportion of farmers						
	Overall	Bean farmers			Maize farmers		
		Overall	Na.	Ad.	Overall	Na.	Ad.
Government extension	0.582	0.531	0.469	0.560	0.629	0.522	0.645
Fellow farmer	0.346	0.324	0.287	0.341	0.366	0.246	0.383
NGO	0.267	0.317	0.397	0.283	0.219	0.232	0.217
NARO	0.261	0.317	0.275	0.335	0.208	0.181	0.212
Farmer organizations	0.154	0.168	0.166	0.169	0.141	0.174	0.136
Agro input dealer	0.088	0.066	0.022	0.086	0.109	0.109	0.110
Seed companies	0.070	0.051	0.053	0.050	0.089	0.043	0.095
Local shop	0.027	0.020	0.016	0.022	0.033	0.014	0.035
University	0.009	0.015	0.022	0.012	0.003	0.000	0.003
Vocational training	0.002	0.001	0.000	0.001	0.003	0.007	0.002
Other source	0.023	0.021	0.024	0.031	0.017	0.022	0.025

### Information channels

Different Information channels used by famers are shown in Table 7. Extension was the major source of information (63%). This was followed by radio programs, (44%), farmer -to -farmer, (40%) and research outreach (13%). This is a normal behaviour hence the non-significance of observations. TV and trade fairs were lowly used as information channels but their use between adopters and nonadopters turned out to be significantly different with adopters having an edge.

**Table 7: Information channels of adopters and non-adopters**

Mode of information Source	Proportion of farmers						
	Overall	Bean Nonadopter	Bean Adopte	P stat	Maize Nonadopter	Maize Adopter	P stat
Extension training	0.632	0.600	0.657	0.0799	0.572	0.632	0.1752
Radio programme	0.441	0.372	0.413	0.2146	0.442	0.486	0.3390
Farmer-to-farmer	0.408	0.416	0.382	0.3096	0.435	0.421	0.7677
Research outreach	0.130	0.175	0.165	0.6855	0.080	0.096	0.5382
Farmer field schools	0.098	0.119	0.116	0.9114	0.072	0.081	0.7420
Farm clinics	0.049	0.037	0.062	0.1042	0.036	0.044	0.6590
TV programmes	0.047	0.003	0.079	0.0000	0.000	0.043	0.0126
Trade fairs	0.032	0.006	0.054	0.0002	0.007	0.028	0.1489
SMS	0.020	0.009	0.018	0.2964	0.000	0.028	0.0470
Newspaper	0.010	0.000	0.006	0.1825	0.014	0.015	0.9287
Posters	0.005	0.013	0.006	0.2355	0.007	0.001	0.1082
Internet	0.004	0.009	0.001	0.0544	0.000	0.004	0.4498
Other information	0.037	0.034	0.054	0.1715	0.007	0.029	0.1362

Note: p-values are based on the chi statistic

### 3.2.2 Farmer training and use of promoted technologies

#### Training on agricultural practices

For the period 2016 through 2020, the percentage of farmers trained on different technologies and practices was about 50 percent (Figure 3.) More adopters (58%) received training as compared to non-adopters (31%) and this is further reflected by a similar trend among crops. This agrees with the above observation as farmers who adopt improved varieties are usually the ones targeted for training. Compared with the national figures, the survey conducted in 2019 indicated that less than 5 percent of the farmers received training on agriculture (UBOS, 2019). This may be attributed to the fact that distribution of improved agricultural technologies is normally accompanied with training thus increasing the likelihood of farmers exposed to agricultural information.



Introducing, training and promoting new, improved and popular bean varieties to Mutufu, farmers in Sironko – Helping farmers identify bean pests and



Kabale farmers – supporting and strengthening community bean seed banks

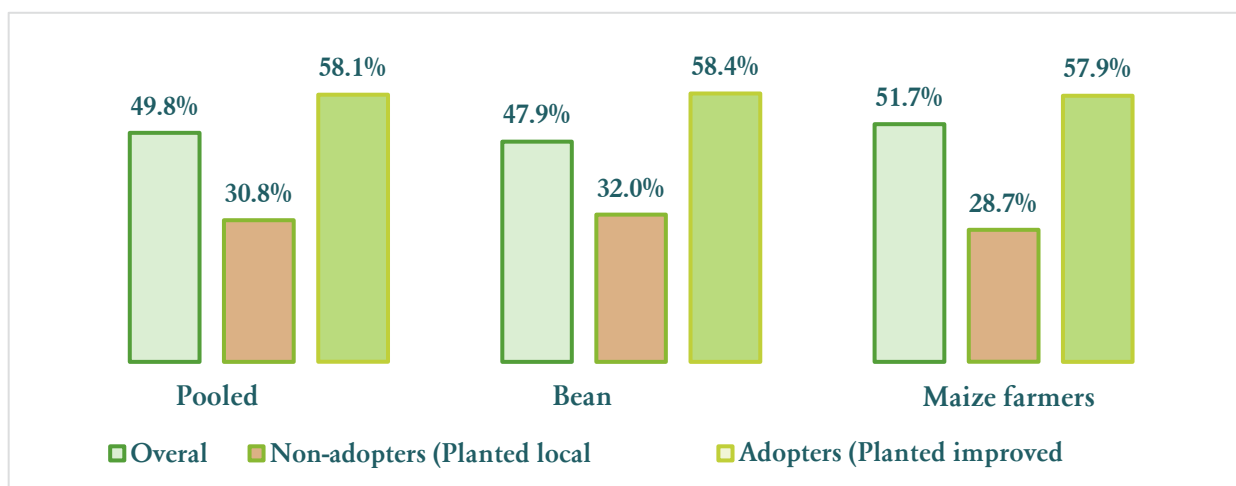


Figure 3: Percent of farmer who received training

Acquired knowledge on practices

Table 8 shows knowledge acquisition about agricultural management practices/ technologies that have been promoted over the years. Over 60 percent of the farmers were knowledgeable about the presence of early maturing varieties. However, for other practices, less than 50 percent of the farmers reported to have acquired knowledge on them.



Farmer weeding bean garden



Variety identification, NABE4

Overall, practices for which farmers acquired knowledge include presence of early maturing varieties (60%), drought tolerant plant varieties (47%) and use of agro-chemical (41%) (Table 8). Specifically, about 68 percent of maize adopters and 70 percent of bean adopters received information on early maturing varieties, also 51 percent of maize and 51% bean farmers respectively received information on drought tolerant varieties.

**Table 8: Accessed knowledge on practices/technologies**

Variable	Percent of farmers				
	Pooled sample	Bean farmers		Maize farmers	
		Na.	Ad.	Na.	Ad.
Early maturing varieties	0.612	0.413	0.701	0.497	0.675
Drought-tolerant plant varieties	0.466	0.345	0.506	0.408	0.512
Use of fertilizers and chemicals	0.411	0.285	0.447	0.287	0.479
Mixed cropping/ Intercropping	0.388	0.299	0.386	0.376	0.436
Use of Hybrid and Quality seed	0.372	0.206	0.391	0.293	0.459
Crop diversification	0.288	0.256	0.289	0.261	0.309
Mixed crop-livestock farming systems	0.270	0.192	0.282	0.248	0.304
Integrated pests and disease management	0.264	0.167	0.282	0.185	0.320
Sustainable use of Soil & water conservation	0.233	0.167	0.256	0.217	0.251
Tree planting	0.231	0.185	0.188	0.236	0.284
Improving soil moisture retention	0.207	0.139	0.202	0.191	0.247
Adjusting planting & harvesting dates	0.199	0.178	0.202	0.178	0.213
Drought tolerant animal breeds	0.163	0.107	0.162	0.159	0.191
Climate smart practices	0.161	0.135	0.172	0.121	0.177
Small scale irrigation	0.158	0.096	0.172	0.121	0.187
Kitchen gardening	0.150	0.128	0.127	0.146	0.179

Agro-forestry; Food preservation	0.138	0.125	0.132	0.146	0.146
Mechanization	0.134	0.078	0.127	0.121	0.168
Food processing & value chain management	0.103	0.068	0.094	0.121	0.122
Fodder preservation	0.077	0.057	0.073	0.102	0.082
Protection and restoration of ecosystem	0.074	0.046	0.082	0.051	0.088
Increasing use of climate forecasting	0.066	0.046	0.049	0.064	0.088
Solar technology & agric. weather advisory	0.053	0.043	0.040	0.051	0.067
Biofortification	0.025	0.032	0.031	0.000	0.024
Other	0.008	0.011	0.009	0.000	0.007

### Specific farmer trainings

The study further investigated the special trainings farmers received on variety attributes and the related agronomic practices. From the results presented in Table 9, most farmers reported training on early maturing varieties (46% bean adopters, maize 44%), drought tolerant (30% for both bean and maize adopters), use of fertilizers and chemicals (24% beans, 25% maize), intercropping (21% beans, 22% maize) and use of quality seed (16% bean adopters and 22 percent maize adopters). Technological packages released by NARO on individual varieties tend to prioritize these areas. Early maturing attribute is promoted by NARO to increase food availability within shortest time possible. Drought tolerant varieties aim to respond to climate change, a common phenomenon currently and promotion of use of quality seed for improved productivity. Intercropping a practice that farmers use to maximise land and labour factors of production. In future, as farmers try to cope against increased pest and diseases, low moisture, and climate change, areas of training should be expanded to include climate smart practices, soil and water conservation, agro-forestry and integrated pest and disease management.

**Table 9: Practices for which training was received**

Variable (TAP)	Percent of farmers					
	Bean farmers			Maize farmers		
	Overall	Na.	Ad.	Overall	Na.	Ad.
Early maturing varieties	0.357	0.210	0.454	0.387	0.197	0.438
Drought-tolerant plant varieties	0.231	0.117	0.306	0.256	0.121	0.292
Use of fertilizers and chemicals	0.195	0.135	0.235	0.225	0.121	0.253
Mixed cropping/ Intercropping	0.161	0.085	0.212	0.199	0.134	0.216
Use of Hybrid and quality seed	0.126	0.071	0.162	0.188	0.064	0.222
Crop diversification	0.109	0.093	0.120	0.135	0.096	0.146
Mixed crop-livestock farming systems	0.075	0.039	0.099	0.106	0.057	0.119
Soil & water conservation	0.075	0.036	0.101	0.103	0.045	0.119
Drought tolerant animal breeds	0.074	0.039	0.096	0.077	0.045	0.086
Integrated pests and disease management	0.069	0.050	0.082	0.124	0.051	0.144
Improving soil moisture retention	0.057	0.039	0.068	0.066	0.025	0.077
Tree planting	0.052	0.028	0.068	0.087	0.025	0.103
Adjusting planting & harvesting dates	0.047	0.028	0.059	0.064	0.038	0.070
Climate smart practices	0.042	0.039	0.045	0.058	0.006	0.072

Small scale irrigation	0.037	0.018	0.049	0.069	0.006	0.086
Agro-forestry; Food preservation	0.031	0.032	0.031	0.037	0.032	0.038
Mechanization	0.030	0.014	0.040	0.050	0.025	0.057
Kitchen gardening	0.023	0.021	0.024	0.053	0.025	0.060
Food processing & commodity value chain	0.013	0.004	0.019	0.028	0.019	0.031
Fodder preservation	0.008	0.007	0.009	0.027	0.013	0.031
Protection and restoration of ecosystem	0.008	0.000	0.014	0.023	0.006	0.027
Increasing use of climate forecasting	0.008	0.007	0.009	0.009	0.000	0.012
Biofortification	0.006	0.004	0.007	0.004	0.000	0.005
Agricultural weather advisory	0.004	0.004	0.005	0.015	0.000	0.019
Other	0.013	0.007	0.016	0.007	0.000	0.009

### Applied the technology after training

For technologies/innovations/methods/practices (TIMPs) for which training was received, there was a high propensity for application in the field. About 75 to 85 percent of the surveyed farmers reported to have applied the knowledge from the training implying that about 8 out of 10 farmers were likely to apply the knowledge (Fig. 4). The results further reveal that even for the nonadopters, the percentage of farmers that got training and applied it was not significantly different from that of adopters. This indicates that training of farmers is an important pathway to enhancing production.

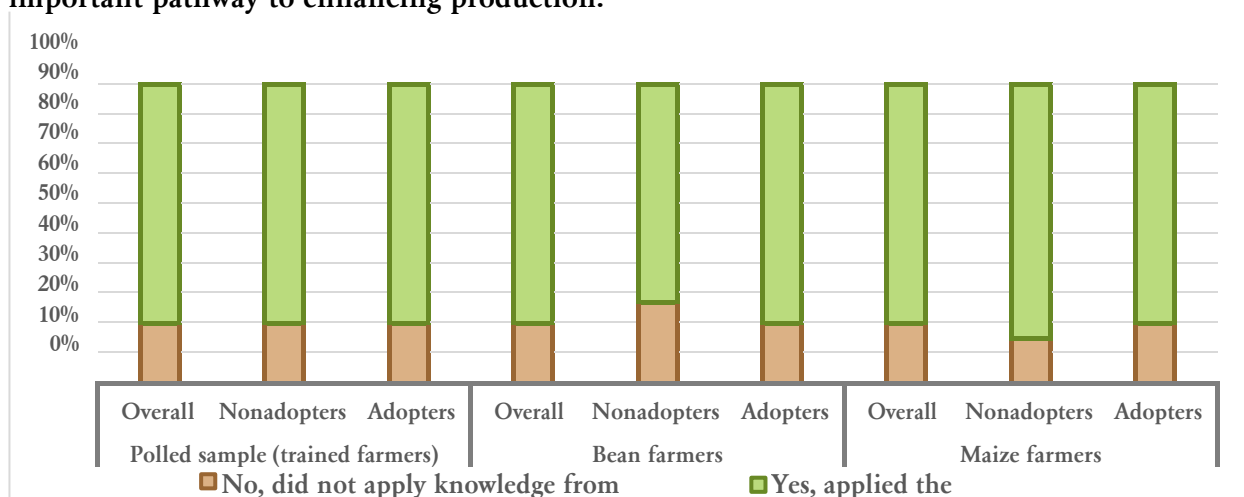


Figure 4: Agricultural extension training and application of knowledge

### Perceived benefit from training

In Figure 5, it is shown that many farmers (74%) considered the trainings received to be beneficial and the percentage was even higher for the adopter category of farmers ranging between 84 to 87 percent as compared to 13 to 55 percent for nonadopters.

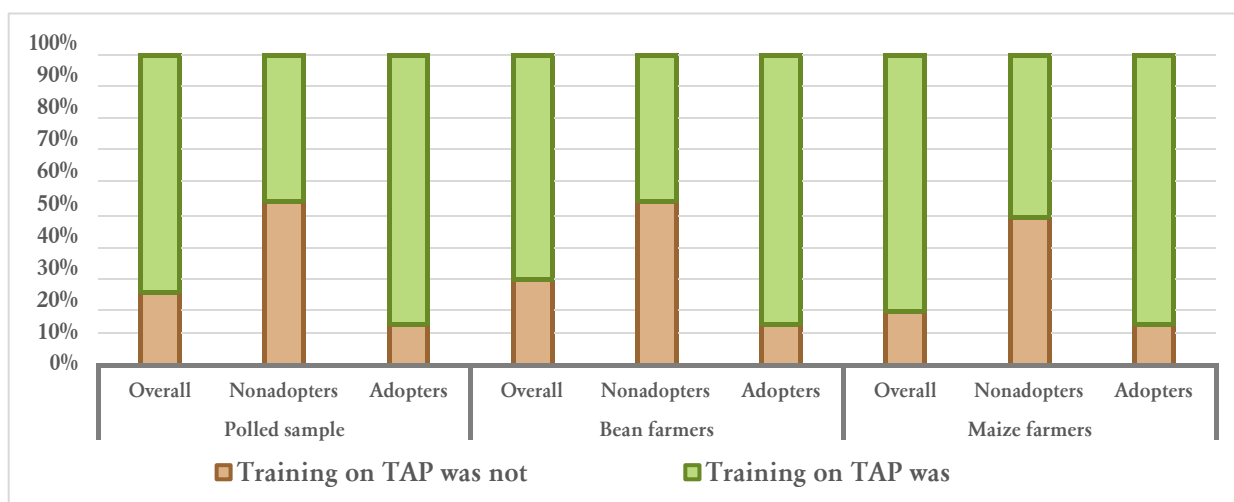


Figure 5: Percent of farmers acknowledging training to be beneficial

The 26 percent that did not find the training to be beneficial (Fig. 5) can be attributed to the fact that extension driven training may at times not be well targeted since the prior assumption by the agent is that every participant present needs the same knowledge. However, a demand led extension service as was with NAADS may sometimes be more beneficial in offsetting such anomaly.

### 3.3. Technology adoption and production

This section presents adoption of NARO technologies categorized into varieties, practices, and complementary agro-inputs; level and intensity of technology adoption; production, productivity, and yield gaps for beans and maize farmer categories.

#### 3.3.1 General level of technology adoption

Figure 6 shows the level of adoption of improved beans and maize varieties among the farmers. Generally, over the context of the five-year period (2016-2020), 70 percent of the households had adopted improved NARO bean and maize varieties. Of this, approximately 79 percent and 60 percent of the households had adopted improved bean and maize varieties, respectively.

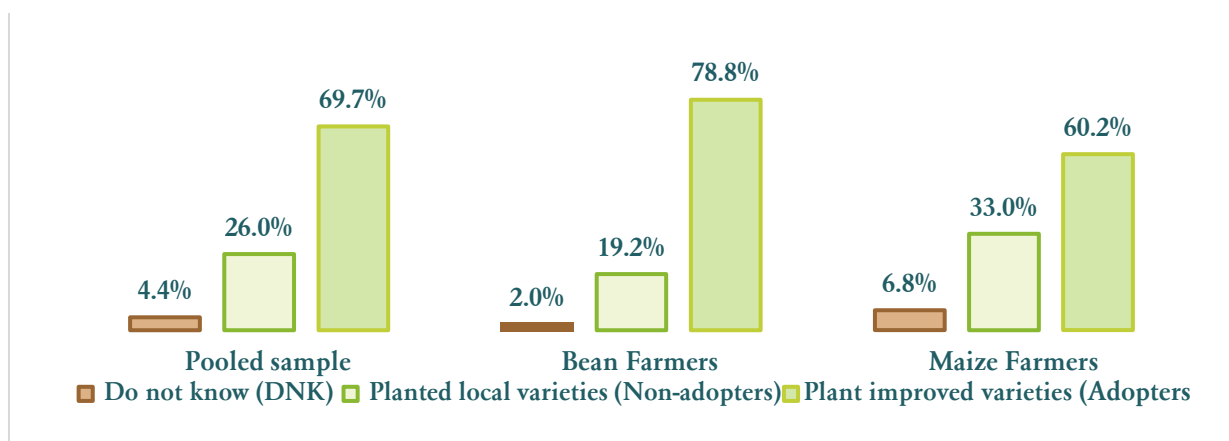


Figure 6: Adoption of improved seed technologies

Alluding to insights from FDGs, beans and maize are considered as seasonal crops, which are easier to manage and can easily adapt to existing farming systems. Beans are easily recycled and intercropped with other crops which makes their adoption widespread. These crops were also grown for income and food security as reported by farmers.

*“We mostly produce beans for food security, and we sell some. If I harvest 50kgs I can sell 30kgs and remain with maize. We produce an average of ¼ acre of maize per season. Very few of us grow maize for income because we don’t have land except in Kitongo and Nakaziba”* (Butayunja men and women FGD, 19<sup>th</sup> February 2021)

#### Level of technology adoption by ZARDI

Level of adoption is influenced by several factors including heterogeneity of farmer characteristics and geographic or agro-ecological zones which differ by weather conditions. In Table 10, the overall adoption of improved bean and maize varieties across the zones is shown. BUGIZARDI (85%) followed by BUZARDI (76%) and NGETTA (73%) had the highest adoption levels of improved varieties. The adoption of the bean and maize varieties varied across zones. For example, adoption of beans was highest in BugiZARDI (79%) and MUZARDI (70%) while maize was observed to be highest in BUZARDI (89.2%) and BugiZARDI (88.9%). The high adoption of maize in BugiZARDI is explained by the fact that maize has become a key staple crop in the zone due to destruction of banana by pests and diseases.

Table 10: Adoption levels by ZARDI

ZARDI	Proportion of farmers								
	Overall			Beans			Maize		
	DNK	Local	Improved	DNK	Local	Improved	DNK	Local	Improved
ABIZARDI	0.020	0.477	0.503	0.010	0.520	0.469	0.030	0.436	0.535
BUGIZARDI	0.030	0.123	0.847	0.051	0.154	0.794	0.015	0.101	0.884
BUZARDI	0.105	0.133	0.762	0.275	0.175	0.550	0.000	0.108	0.892
KAZARDI	0.137	0.578	0.284	0.137	0.578	0.284	0.000	0.000	0.000
MUZARDI	0.044	0.226	0.730	0.052	0.246	0.702	0.036	0.206	0.758
NGETA	0.010	0.258	0.732	0.024	0.415	0.561	0.000	0.157	0.843

Note: DNK denotes do not know

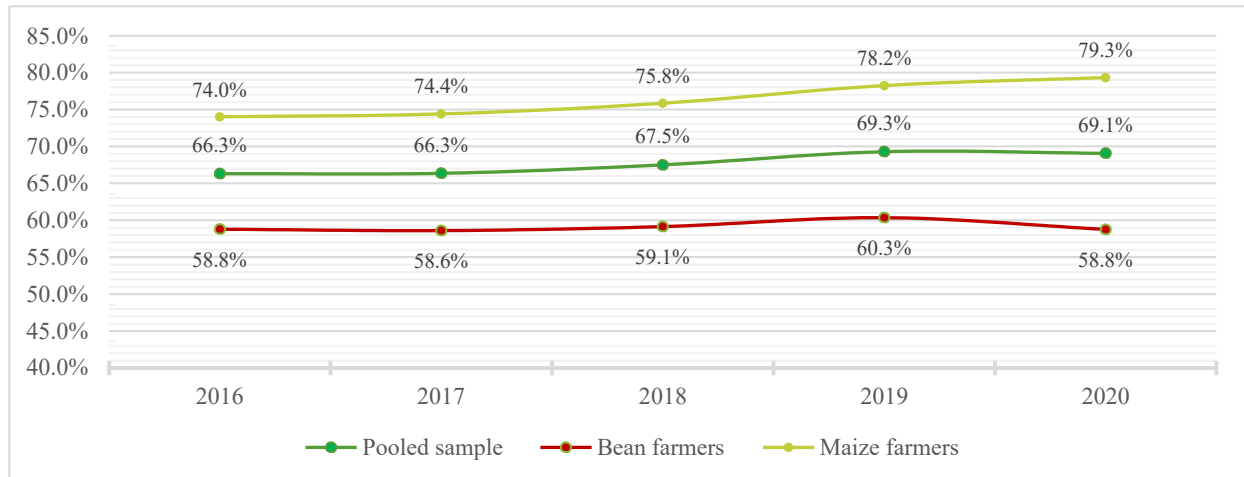
Higher adoption of maize in the Albertine region was attributed to its significant contribution to household income compared to cassava that was perceived to be more of a food security crop in the region. Farmers have recently switched to maize because it attracts better prices and largely promoted by several actors compared to cassava as confirmed by FGDs and key informants. Similarly, in MUZARDI, it was revealed that maize was perceived to be more of a cash crop than for food security.

*One of the districts that has high production of maize in the region compared to beans although produced at subsistence level. Some of the organizations that have promoted these seeds are NGOs, World vision, HOCADDO-Hoima Caritas district, HODFA-Hoima district farmers' association, Government programs under MAAIF like ACDP-Agriculture cluster development project which is currently promoting maize and Bazooka which matures in 4 months" (Key informant, Kikuube sub-county, Kikuube district*

Although both crops significantly contribute to food and income security, beans were recognised to contribute more to food security relative to maize.

#### Trend on level of adoption of improved seed

The level of adoption of NARO technologies generally registered a gradual increase over the five years (Figure 7). It is also shown that the adoption trend maize farmers were at a higher level as compared to that of bean farmers. Over the five years, adoption level of bean technologies was consistently over 65 percent while maize was above 70 percent. The increase in the trends of adoption for the two commodities was gradual over the five-year period.



**Figure 7: General trend on level of adoption of improved seed technologies**

The high level of adoption of improved bean and maize seed could partly be attributed to; accessibility, ability to be replanted and high popularization through multi stakeholder platform mechanism and pathways including seed companies, farmer seed producer cooperatives, and local seed businesses. The slight drop in variety adoption for both crops in 2020 (Figure 6) could be attributed to the negative effects of COVID which affected farmers purchasing power and access to agro- inputs including seed.

#### Number of bean varieties released for adoption

In the last decade, NARO research under the beans programme has developed varieties that are; higher in micronutrients, resistant to multiple biotic and abiotic stresses including pests and diseases, with consumer and market preferences, suitable to different agro ecologies, maximize yield and use the available resources efficiently.



Breeding lines of beans at NaCRRRI- Namulonge.

Among these new varieties are a special set of five bio-fortified with enhanced levels of iron and zinc, significantly above the normal bean varieties. These varieties are a source of rare micronutrients to resource-poor farmers, especially undernourished children, and lactating mothers. More than 10 seed companies are currently engaged in commercialization of improved bean seed. From the FGD, respondents confirmed that technological and consumer attributes are key drivers for technology adoption. Technological attributes majorly contributed to the quantities produced so farmers are assured of bigger volumes reserved for sale and consumption.

Figure 8 shows the cumulative number of bean varieties that have been developed and released by NARO over the past three decades and it emerges that from 2016 through 2020, 34 bean varieties have been released cumulatively. It is also found that more varieties (20 out of 34, :: 60%) have been released between 2006 and 2020 compared to the period 1990 to 2005. This means that investment in technology development has gradually improved over the years.

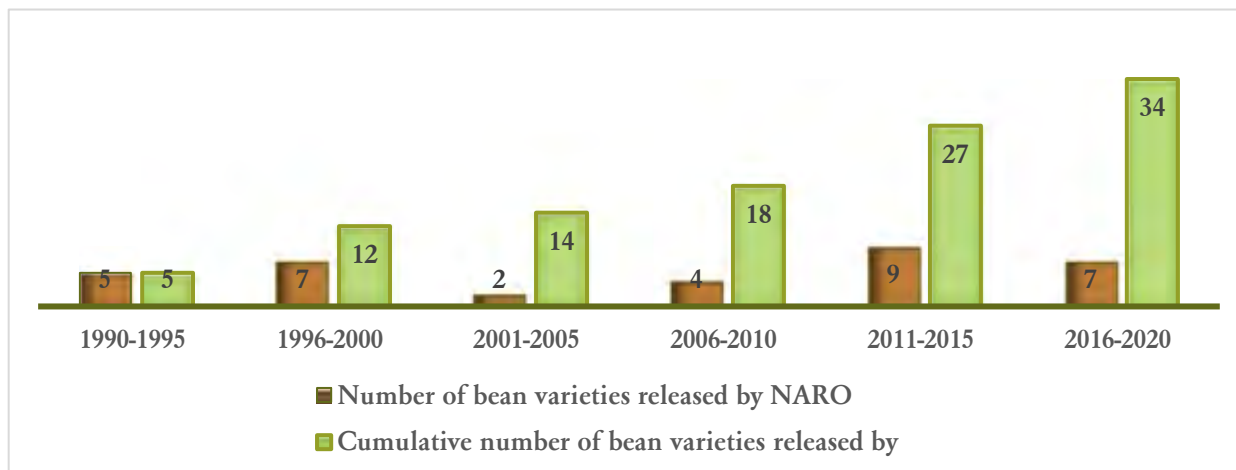


Figure 8: Bean varieties released by NARO

The number of bean varieties developed and released reflects an increased investment in technology development and released by government and development partners over the past 15 years.

#### Bean variety technology adoption

Among the NARO released bean varieties, the most popular variety is found to be K132 followed by NABE 15 and NAROBAN 2 (Table 11). In the top seven improved varieties, five varieties are those released between 2010-2020 namely NABE 15, NABE 17, NAROBAN 1, NAROBAN 2, and NAROBAN 3 while NABE 12C and K132 are quite old varieties but still popular among farmers and consumers in Uganda.



NAROBAN1 variety-rich in Fe & Zn

It is also noted that the NAROBAN (1-6) series of varieties were released between 2015 and 2020 and the results show that farmers are taking them up and it is likely that some of the old varieties are being replaced.

Thus, with more effort in technology promotion, it is possible some of the older varieties will be completely displaced by newer releases. For instance, promotion of NAROBAN 1 may likely wipe

out NABE4 which has some resemblance in colouration and taste yet NAROBAN 1 is nutritionally better because it has a higher content of Fe and Zn to contribute to the fight against malnutrition.

During FGDs participants revealed that NAROBAN 2 and NAROBAN 3 were mainly adopted because they are high yielding, marketable, palatable, and easy to cook. Although, rains affect NAROBAN 3 variety, it fetches much higher price than other varieties. At the time of the study whereas other varieties were sold at UGX 1500 to UGX 2000 per kilogram, NAROBAN 3 was fetching UGX 3000 to 3500 per kilogram, prices that on average were over 50 percent higher than the prices for old varieties.

**Table 11: Bean variety adoption**

Variety	Year of release	Percent of farmers		
		Overall	Nonadopters	Adopters
K-132	1994	10.5	-	17.2
NABE 1	1995	1.1	-	1.7
NABE 2	1995	0.6	-	1.0
NABE 4	1999	2.2	-	3.7
NABE 5	1999	1.6	-	2.6
NABE 6	1999	0.9	-	1.5
NABE 12C	2003	6.4	-	10.5
NABE 14	2006	0.8	-	1.3
NABE 15	2010	8.8	-	14.4
NABE 16	2010	2.6	-	4.3
NABE 17	2012	4.9	-	7.9
NABE 19	2012	0.2	-	0.3
NABE 20	2012	0.1	-	0.2
NABE 22	2012	0.1	-	0.1
NABE 23	2012	1.5	-	2.4
NAROBAN 1	2016	3.7	-	6.0
NAROBAN 2	2016	7.5	-	12.2
NAROBAN 3	2016	5.2	-	8.5
NAROBAN 4C	2016	1.3	-	2.1
NAROBAN 5C	2016	1.1	-	1.8
NAROBAN 6	2019	0.2	-	0.3
LOCAL VARIETY	-	32.6	84.2	-
UNKNOWN VARIETY	-	6.1	15.8	-

Note: Farmers who said that they did not know the variety planted were placed in the category of nonadopters

Indeed, information from research indicated that NABE series varieties released between 2010 and 2013 are high yielding (1800-2500 kg/ha), early maturing (58-120 days), palatable, and tolerant to diseases such as anthracnose, BCMV, and ALS (Nkalubo, 2020). The recently released NAROBAN series of bean varieties such as NAROBAN 1, and NAROBAN 2 have higher yield (1.9-3.8 MT/Ha), very palatable and have a shorter maturity period of 58-88 days. These varieties are also tolerant to anthracnose, BCMV, Rust ALS and other diseases.

### Type of maize varieties planted

Maize seed is in two categories that is the Open Pollinated Varieties (OPV) and the hybrid varieties. Figure 9 shows that 52 percent of farmers grew hybrid maize whereas 27 percent grew OPV maize. However, 86 percent of nonadopters did not know what kind of maize they were growing while 63 percent of adopters grew hybrid maize. Some of the improved maize includes LONGE 10H and LONGE 5 (Annex x).

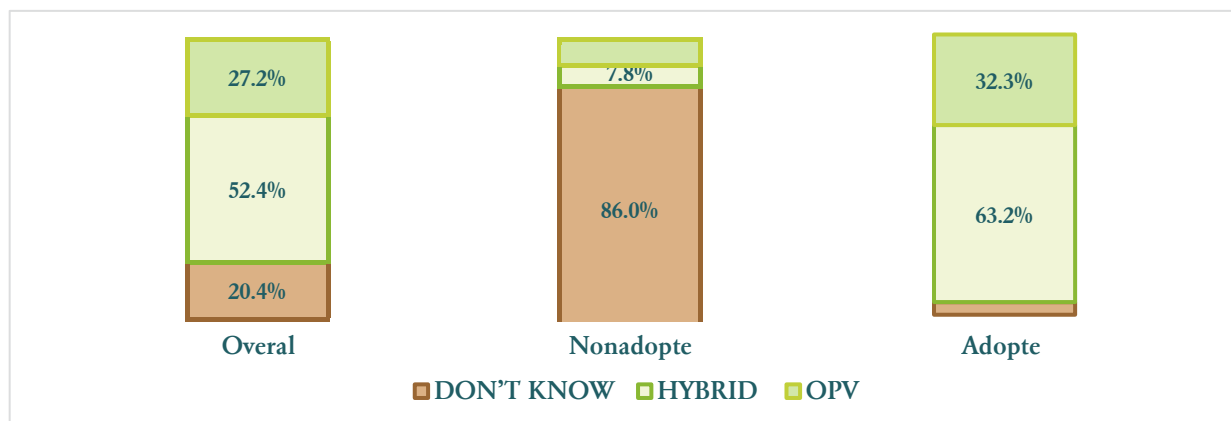


Figure 9: Maize varieties released

Improved maize varieties were, largely adopted by the participating farmers due to existence of public and private sector actors such as NARO, public extension agents under NAADS and district local governments, community-based organisations, and non-government organisations. The high use of LONGE 5 was partly attributed to; accessibility (affordability), ability to be replanted (being an Open Pollinated Variety (OPV), and high popularization through different technology pathways. Farmers mainly adopted LONGE 10H due to its yield attribute, cost and compatibility compared to other varieties like DK and BAZOOKA across the zones. For example, the cost of BAZOOKA was UGX. 10000 compared to LONGE 10H of UGX. 7000 per kilo. Results from the FGD confirmed that.

*“For maize, we grow LONGE 5, Kinoni, bazooka, local seed (munandi, and sometimes Kawanda). But LONGE 10 is more popular. We plough the garden, we spray with weed master before planting, plant 3-4 seeds to ensure that we don't lose (Sekanyonyi FGD, 18<sup>th</sup> Feb 2021).*

*“Most maize has been affected by ear rot especially Bazooka that takes too long in the field before harvest. LONGE series were introduced during the NAADS period like LONGE 5 and 10. They are still appreciated by farmers because they can be replanted for next season though hard to differentiate them in field unlike hybrids that give low yields if replanted” (Key informant, Kikuube district)*

The existence of government programs like the agricultural cluster development program across the zones which provided farm inputs for maize; through the public extension system contributed to the adoption of improved varieties as confirmed by respondents.

#### Farmer preferred variety attributes

Various reasons are associated with farmer adoption of bean and maize varieties namely taste, yield, drought tolerance among others. Table 12 shows that generally, yield (69%), seed availability (34%), and early maturity traits are the top three indicative drivers of variety choice. However, for beans, taste and market demand are key. Much as there are significant differences in the percentages of adopters and nonadopters for each considered, trait, yield, seed availability, and market demand stand out for both categories of farmers.



NARO scientist examining maize infested with maize streak virus.

**Table 12: Farmer preferred variety attributes**

Reason	Proportion of farmers						
	Overall	Bean farmers			Maize farmers		
		All	Nonadopters	Adopters	All	Nonadopters	Adopters
Taste	0.202	0.319	0.311	0.324	0.129	0.192	0.113
Availability of seed	0.339	0.314	0.442	0.233	0.356	0.529	0.312
Early maturity	0.342	0.390	0.329	0.428	0.311	0.132	0.356
Market demand	0.286	0.471	0.269	0.599	0.169	0.073	0.194
Pest/disease resistance	0.108	0.122	0.175	0.088	0.099	0.156	0.084
Drought tolerance	0.210	0.171	0.184	0.163	0.235	0.156	0.255
Easy to cook	0.056	0.144	0.187	0.116	-	-	-
High yielding	0.689	0.658	0.549	0.727	0.709	0.337	0.802
Less labour intensive	0.020	0.044	0.078	0.023	0.004	0.002	0.004
Others	0.043	0.025	0.040	0.015	0.055	0.112	0.041

Despite maize being a man's crop, majority of women farmers in both FHH and MHH on the other hand, reported increased adoption maize varieties such as LONGE 5, LONGE 10H, and PANNAR for their good attributes.

#### 3.3.2 Access to seed

##### Source of seed

Timely access to seed is another challenge to farmers and it can only get worse when it comes to quality-improved seed. Seed is accessed highest from saved seed of the previous season harvest (farmer saved seed 65%; own saved seed 38%) shown in Table 13. Use of farmer saved seed is higher among bean farmers compared to maize farmers. Similarly, it was higher among non-adopters as

compared to the adopters. Farmers who got seed from the agro-input shops where improved seed is sold stood at a dismal 10 percent though slightly higher among adopters of improved maize varieties. Most of the seed therefore used by farmers is recycled which compromises farm yields. This is more pronounced in hybrid maize varieties. Despite the efforts by government to provide improved seed through such programmes as NARO, NAADS/OWC and efforts by farmers to produce seed through farmer groups, very few farmers indicated them as a source of seed. Strategies to provide farmers with sufficient improved seed through government efforts should be developed to enhance farmers' productivity at farm level.

**Table 13: Source of seed**

Source of seed	Proportion of farmers						
	Overall	Beans	Maize	Beans		Maize	
				Nonadopters	Adopters	Nonadopters	Adopters
Fellow farmer	0.268	0.292	0.253	0.304	0.283	0.274	0.246
Own saved seed	0.383	0.518	0.299	0.604	0.448	0.600	0.210
Farmer saved seed	0.651	0.81	0.552	0.908	0.731	0.874	0.456
GOVT/NAADS/ OWC	0.100	0.052	0.129	0.013	0.084	0.054	0.152
NARO	0.045	0.051	0.041	0.011	0.084	0.000	0.054
NGO	0.044	0.057	0.036	0.023	0.084	0.035	0.036
Farmer group (FA)	0.092	0.075	0.104	0.023	0.116	0.042	0.122
Input shop	0.100	0.011	0.155	0.013	0.010	0.044	0.188
Local grain market/shop	0.161	0.148	0.169	0.152	0.146	0.089	0.193
Other (Donation, x)	0.010	0.011	0.009	0.011	0.012	0.000	0.012

### 3.3.3. Intensity of adoption

#### Trend on intensity of adoption

The proportion of land allocated to improved varieties was estimated as a proxy for the intensity/rate of adoption of improved varieties. The results show that the intensity of adoption of improved bean seed by adopters was highest in three years; 2017, 2019 and 2020. The results further show that for maize, the intensity of adoption for improved seed (by adopters) is greater than the intensity of adoption of non-improved seed (by nonadopters) for most of the years in context. The intensity of adoption (in percentage terms) of beans was above 33 percent among adopters and above 44 percent among maize adopters (Table 14). This implies the rate of adoption of maize seed has increased compared to previous findings that showed adoption rate was at 24 percent in 2015 among farmers who had access to improved seed (Simtowe et al., 2019). This means more area was grown under improved varieties as compared to the land races. It thus likely that besides expansion of area under production and other factors, technology adoption has contributed to Uganda's continued increase in output for both beans and maize.

**Table 14: Rate of technology adoption**

Year	Mean (proportion)							
	Area allocation to crop (ha)		Intensity by type of bean seed			Intensity by type of maize seed		
	Beans	Maize	Nonadopters	Adopters	P stat.	Nonadopters	Adopters	P stat.
2016	0.309	0.416	0.285	0.327	0.1328	0.324	0.448	0.0004
2017	0.324	0.425	0.283	0.354	0.0097	0.325	0.459	0.0001
2018	0.334	0.418	0.320	0.344	0.3649	0.341	0.442	0.0011
2019	0.350	0.447	0.309	0.377	0.0032	0.361	0.470	0.0004
2020	0.353	0.435	0.318	0.377	0.0084	0.335	0.461	0.0000

Note: The proportions are in relation to available total arable land vs allocation for crop production by the farmer

### 3.3.4. Factors influencing adoption of NARO improved technologies

Factors that influenced adoption of NARO technologies following a logistic regression were access to information, technology availability, yield, and market demand for the produce, location, and type of enterprise. Early maturity and access to credit were specific factors for maize and beans respectively (Table 15). Access to information enables farmers to learn the requirements of the technology especially agronomic practices. The availability of the technology enabled farmers to access the technology such as seed and inputs. High yields and market availability enabled farmers to harvest high volumes with assurance of markets. Location of farmer to a specific zone influenced the type of enterprise to engage in. For example, beans and maize were taken as key enterprises in western region, while chances to adopt maize were higher in Eastern region. As an enterprise, farmers preferred maize to beans given its importance in household food security and income.

Considering the evidence presented, strategies therefore should be developed towards improvement in extension for increased access to information, research, and development for generation of technologies, improved rural finances and marketing. Such strategies would result into improved technology adoption by farmers.

Table 15: Marginal effects of a Logistic regression on factors influencing adoption

Explanatory variable (Dep. Variable Adopter=1)	Pooled sample of farmers			Maize farmers			Bean farmers		
	Coeff.	Std. Err.	P>z	Coeff.	Std. Err.	P>z	Coeff.	Std. Err.	P>z
Male headed HH	0.0546	0.0252	0.0300	0.0620	0.0321	0.0530	0.0505	0.0378	0.1810
Age of HH head	-0.0364	0.0400	0.3630	-0.0221	0.0548	0.6860	-0.0215	0.0593	0.7170
HH head school	0.0017	0.0024	0.4750	0.0026	0.0031	0.3880	0.0006	0.0037	0.8760
Dependency ratio	-0.0066	0.0414	0.8740	0.0215	0.0537	0.6890	-0.0167	0.0654	0.7990
Access to tech info.	0.1265	0.0214	0.0000	0.1145	0.0271	0.0000	0.1170	0.0334	0.0000
Access to credit	0.0458	0.0220	0.0370	0.0044	0.0278	0.8730	0.0726	0.0337	0.0310
NFI to HHI (Prop.)	0.0534	0.0361	0.1390	0.0187	0.0464	0.6860	0.0687	0.0538	0.2010
Technology availability	-0.1065	0.0217	0.0000	-0.0369	0.0263	0.1610	-0.1213	0.0352	0.0010
Early maturity trait	0.0647	0.0230	0.0050	0.1072	0.0317	0.0010	0.0388	0.0354	0.2740
Mkt demand for the produce	0.1231	0.0250	0.0000	0.0461	0.0389	0.2360	0.1694	0.0321	0.0000
P&D tolerance trait	-0.0867	0.0314	0.0060	-0.0373	0.0372	0.3160	-0.0805	0.0487	0.0980
Yield	0.1945	0.0188	0.0000	0.2354	0.0216	0.0000	0.1461	0.0315	0.0000
Land access	-0.0018	0.0033	0.5950	-0.0027	0.0027	0.3150	-0.0004	0.0048	0.9380
Eastern region	0.1084	0.0316	0.0010	0.1104	0.0358	0.0020	0.1045	0.0500	0.0370
Western region	-0.1366	0.0298	0.0000	0.1227	0.0543	0.0240	-0.2692	0.0425	0.0000
Northern region	-0.0631	0.0270	0.0190	-0.0191	0.0307	0.5330	-0.1067	0.0431	0.0130
Enterprise type (Maize, 1/0)	0.1761	0.0218	0.0000						

Note: HH denotes household; NFI means nonfarm income; and P&D denotes pest and disease. N=1427

### 3.3.5 Use of complementary inputs

#### Adoption of complementary inputs

For optimal performance of improved seed, other complementary technologies such as fertilizers, pesticides, and other agricultural inputs are required (Acheampong et al., 2021). Use of complimentary inputs among smallholder farmers in Uganda increased from 14 percent to about 47 percent, with maize adopters at 56 percent and 45 percent for bean adopters (Table 16). This implies that the use of complementary inputs in Uganda is low. Strategies to popularise on-farm demonstrations to show the importance of these complementary inputs should be put in place.

**Table 16: Level of adoption of complementary inputs**

Year	Proportion of farmers						
	Pooled sample	Bean farmers			Maize farmers		
		Overall	Nonadopters	Adopters	Overall	Nonadopters	Adopters
2016	0.143	0.118	0.103	0.127	0.166	0.083	0.189
2017	0.167	0.137	0.103	0.160	0.195	0.115	0.216
2018	0.242	0.214	0.157	0.252	0.269	0.166	0.297
2019	0.370	0.333	0.292	0.360	0.406	0.236	0.452
2020	0.468	0.412	0.363	0.445	0.521	0.363	0.564

Note: the set of complementary inputs includes pesticides, fertilizers, and herbicides.  
A farmer applying either of the 3 was considered a user of complementary inputs

#### Use of complementary inputs by gender of household head

Often than not, women are more resource constrained compared to men in terms of access to productive resource factors such as fertilizers and pesticides. Generally, results in Table 17 show that the percentage of farmers that use complementary inputs is higher among male headed households compared to female headed households for both beans and maize in the 2016 – 2020 period.

In 2020 for instance, 56 percent of male-headed maize farmer households used complementary inputs as compared to only 36 percent for female headed households. Similarly, about 43 percent of male-headed bean farmer households used complementary inputs as compared to 35 percent for female headed households in 2020. This is attributable to the fact that generally, women are more resource constrained compared to men thus having less access to productive resource factors such as fertilizers (Njobe & Kaaria, 2015).

**Table 17: Use of complementary inputs across households by gender of the head**

Year	Proportion of farmers			
	Bean farmers		Maize farmers	
	FH household	MH household	FH household	MH household
2016	0.098	0.124	0.083	0.189
2017	0.109	0.147	0.115	0.216
2018	0.142	0.239	0.166	0.297
2019	0.273	0.354	0.236	0.452
2020	0.355	0.432	0.363	0.564

Note: FH denotes female headed while MH denotes male headed

Farmers mostly used inorganic fertilizers (64%) and pesticides (62%) while the least used complementary inputs were cultural (1%) and organic fertilizers (12%) (Table 18). Generally, although use of agro-inputs was on the increase, the use of inorganic fertilizers and pesticides among users and non-users of NARO technologies remains below 45 percent. This concurs with (UBOS, 2018) that indicates that 23 percent of farmers in Uganda were using fertilizers and 21 percent were using agro- chemicals by 2018.

**Table 18: Type of complementary inputs**

Input type (2020)	Proportion of farmers						
	Pooled Sample	Bean farmers			Maize farmers		
		Overall	Nonadopters	Adopters	Overall	Nonadopters	Adopters
Inorganic fertilizers	0.643	0.591	0.490	0.646	0.683	0.702	0.680
Organic fertilizers	0.124	0.155	0.216	0.122	0.101	0.105	0.101
Pesticides	0.618	0.595	0.520	0.635	0.636	0.561	0.649
Herbicides	0.223	0.186	0.176	0.190	0.252	0.298	0.244
Cultural methods	0.006	0.003	0.010	0.000	0.008	0.000	0.009
Others	0.009	0.007	0.020	0.000	0.010	0.000	0.012

### 3.3.6 Application of complementary inputs

Increase in the use of complementary inputs is often influenced by factors such as pests and diseases pressure, need to cut weed management costs and declining soil fertility among others (Acheampong, 2021, p. 45). Generally, farmers in this study used complementary inputs in form of fertilizers, pesticides, and herbicides for maize where they expected more yield and income. According to the FGD, farmers applied fertilizers depending on the extent of soil fertility and there was an increasing trend for use of foliar/liquid fertilizer on the assumption that they were cheaper than granular fertilizers.

Herbicides gained more popularity because they are regarded as alternative options for reducing labour costs and drudgery. Information from the survey and FGDs indeed confirmed that farmers weed once instead of thrice in a season after application of herbicides. They also use herbicides during initial land clearing prior to planting. In the recent past, outbreak of pests such as Fall Army Worm (FAW) in

maize since 2016 (and increase in the prevalence of bean aphids, thrips, and bugs has led to the increase in the use of pesticides like rocket (44EC profenofos and cypermethrin). Indeed, this was expressed by respondents during the explanatory FGDs.

*“In order to obtain more beans, we must use fertilizers like NPK, UREA, Boron and Phosphorous. Although we apply fertilizers depending on the conditions of the soils. We also use vegmax, super grow to improve the appearance of the crop. We use rocket to kill pests and diseases. We also weed to control pests and diseases. But we also use weed master for killing weeds because the workers are quite expensive to weed and plough our gardens”* (Sekanyonyi FGD 18<sup>th</sup> February 2021).

For maize, use of complementary inputs cumulatively increased by 41.1% from the base year (2016) at an average rate of 10.3%.

*“For maize planting we prepare land then apply weed master, dig holes and plant maize. But some of us use fertilizers and plant 2ftX 2ft if the land is infertile, we use DAP, apply two lids of soda cups, cover with soil and plant after we spray with herbicides after 2 weeks, we start weeding and apply vegmax, nutriplant or digro, use pesticides like rocket and other chemicals. At tussling you can apply rocket to control insects”* (Bagezza FGD, 24<sup>th</sup> February 2021).

### 3.3.7 Production, productivity, and yield gaps

#### General farmer production and yield

The average land allocation to beans was 0.5 hectares from which a seasonal harvest of about 500 kgs was derived, giving a yield of about 920 kg $\text{ha}^{-1}$  (Table 19). The results show an improvement in yield from the 2015 level (of 820 kg $\text{ha}^{-1}$ ), but it is still much lower than the research yield of 5 to 6 MT/Ha of NABE bean varieties promoted by NARO.

Maize farmers also allocated an average of about one hectare to maize production and the mean output was about 2220 kgs, yielding about 2200 kg $\text{ha}^{-1}$ . In the case of maize, the yield has not significantly increased in the past five years.

**Table 19: General production of beans and maize**

Variable	Obs.	Mean	Std. Dev.	Min	Max
<b>Beans</b>					
Area planted under beans (ha)	3065	0.519	0.575	0.002	12.141
Quantity of bean harvested (kgs)	3065	497.854	947.181	0.500	15000
Farmer yield (kg/ha <sup>-1</sup> )	3065	920.855	645.439	1.236	4942.103
<b>Maize</b>					
Area planted under maize (ha)	2797	0.959	0.950	0.040	16.187
Quantity of maize harvested (kgs)	2797	2216.802	3136.714	20.00	51000
Farmer yield (kg/ha <sup>-1</sup> )	2797	2173.665	1563.049	37.066	14233.26

### Technology yield gap

In Table 20, the gap in yield of adopter of improved NARO varieties compared to nonadopters was assessed and the evidence shows a significant gap in yield, indicating the benefit of adopting NARO technologies. The results show that on all parameters (area planted, output, and yield), the adopters have an edge over nonadopters. The gap in yield between adopters and nonadopters is estimated to be about 11 percent among bean farmers and 12 percent among the maize farmers. This indicates that land productivity for farmers who adopt improved seed is likely to be 11 percent higher compared to nonadopters. Considering adopters also planted bigger area, results also suggest that there could be an incentive of increased allocation of area under the crop if one is an adopter of an improved agricultural technology.

**Table 20: Technology yield gap**

Variable	Nonadopters		Adopters		Gap	P stat.
	Mean	Std. Dev.	Mean	Std. Dev.		
<b>Beans</b>						
Area planted under beans (ha)	0.395	0.378	0.605	0.666	34.7%	0.0000
Quantity of bean harvested (kgs)	317.914	393.214	622.292	1171.823	48.9%	0.0000
Bean yield (kg/ha <sup>-1</sup> )	860.947	591.847	962.619	677.038	10.6%	0.0000
<b>Maize</b>						
Area planted under maize (ha)	0.659	0.595	1.043	1.012	36.8%	0.0000
Quantity of maize harvested	1447.33	2238.972	2432.776	3314.137	40.5%	0.0000
Maize yield (kg/ha <sup>-1</sup> )	1963.382	1679.293	2232.687	1524.033	12.1%	0.0002

Note: The technology gap in this case is viewed as the difference in yield between adopters and nonadopters due to technology adoption

### Gender yield gap

The results also indicate that irrespective of crop enterprise, the area allocated for production and quantity of production is higher for men compared to that of women headed households (Table 21). However, within gender, there are significant differences (in area planted, output, and yield) between nonadopters, and adopters save for the maize yield of male headed households. For male headed households, the adopters of NARO bean technologies got yield higher than that of nonadopters by 16 percent while the yield was not significantly different for the maize enterprise.

A closer look at the gaps within a crop and between gender considering technology user or nonuser shows that among bean farmers, technology non-adopters in male headed households got



Cleaning beans for home consumption and market

6 percent less yield than that of female headed households while among adopters, female headed households got about 20 percent less yield than that of farmers in male headed households. Conversely, among maize nonadopters, female headed households got 37 percent lower yield than that of male headed households while among adopters yield of female headed households was 17 percent below that of the male headed households. This reveals that yield gaps exist not only between male and female farmers but also extend to adopters and nonadopters within gender for a given crop enterprise. Thus, irrespective of gender, interventions for technology adoption should be broad based and not gender biased to eliminate yield gaps within and between various genders.

**Table 21: Comparison of field size and yield by sex of household head**

Variable	Female headed household				Male headed household			
	Na.	Adopter	Gap	P stat.	Na.	Adopter	Gap	P stat.
<b>Beans</b>								
Area planted (ha)	0.335	0.543		0.0000	0.416	0.624		0.0000
Quantity harvested	298.194	438.35		0.0025	324.656	679.699		0.0000
Bean yield (kg/ha <sup>-1</sup> )	896.654	812.239	-10.4%	0.0754	848.739	1009.55	15.9%	0.0000
<b>Maize</b>								
Area planted (ha)	0.514	0.731		0.0000	0.721	1.095		0.0000
Quantity harvested	813.816	1443.193		0.0001	1721.161	2597.09		0.0000
Maize yield (kg/ha <sup>-1</sup> )	1397.127	1894.248	26.2%	0.0001	2208.142	2288.88	3.5%	0.3427

Note: The yield gap in this case is viewed as the difference in yield between adopters and nonadopters due to technology adoption

### Yield across research agro-ecological zones

Based on the NARO research zonal (ZARDI) jurisdictions, bean farmers in Bulindi ZARDI had the highest land allocation to bean production and, had the highest output and yield compared to the others (Table 22). Bulindi ZARDI and MUZARDI bean farmers had the highest land allocation to bean production (0.8 ha). However, the yields from these two regions were different with Bulindi ZARDI having almost two times higher yield than MUZARDI, 1323 Kgha<sup>-1</sup> and 795 Kgha<sup>-1</sup> respectively (Table 22). This could be attributed to both ecological and climatic factors such soils and amount of rainfall. For maize, output of farmers in BUZARDI, BUGIZARDI, and MUZARDI was comparable with farmers in BUZARDI having the highest yield (2613 Kgha<sup>-1</sup>).

**Table 22: Yield across the different NARO agro-ecologies**

ZARDI	Area (Ha)		Output (kgs)		Yield (kgha <sup>-1</sup> )	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
<b>Bean farmers</b>						
ABIZARDI	0.379	0.267	325.705	256.146	925.790	595.221
BUGIZARDI	0.565	0.355	596.272	742.285	1041.892	669.006
BUZARDI	0.746	0.798	1175.904	2099.315	1323.017	903.642
KAZARDI	0.164	0.135	187.200	199.716	1074.846	608.138
MUZARDI	0.653	0.754	548.333	960.337	795.310	532.356
NGETA	0.531	0.329	308.393	491.969	578.453	501.368
<b>Maize farmers</b>						
ABIZARDI	0.505	0.346	927.830	1433.708	1710.475	1886.121
BUGIZARDI	0.986	0.990	2543.762	3543.731	2341.642	1709.570
BUZARDI	1.012	1.020	2494.444	2541.504	2612.797	1536.479
KAZARDI	-	-	-	-	-	-
MUZARDI	1.071	1.090	2498.333	3602.984	2243.487	1407.385
NGETA	0.835	0.599	1535.231	1946.401	1720.579	1384.232

### 3.3.8 Seasonal variation of farmer yield

#### Seasonal variation in area allocation and yield

Figure 10 shows that much as the yield of adopters was slightly above the general yield trend line (for both bean and maize farmers), overall, the general farmer yield exhibits fluctuation which may be attributed to several factors such as amounts of rainfall, soil types, climate change and farmer agronomic practices.

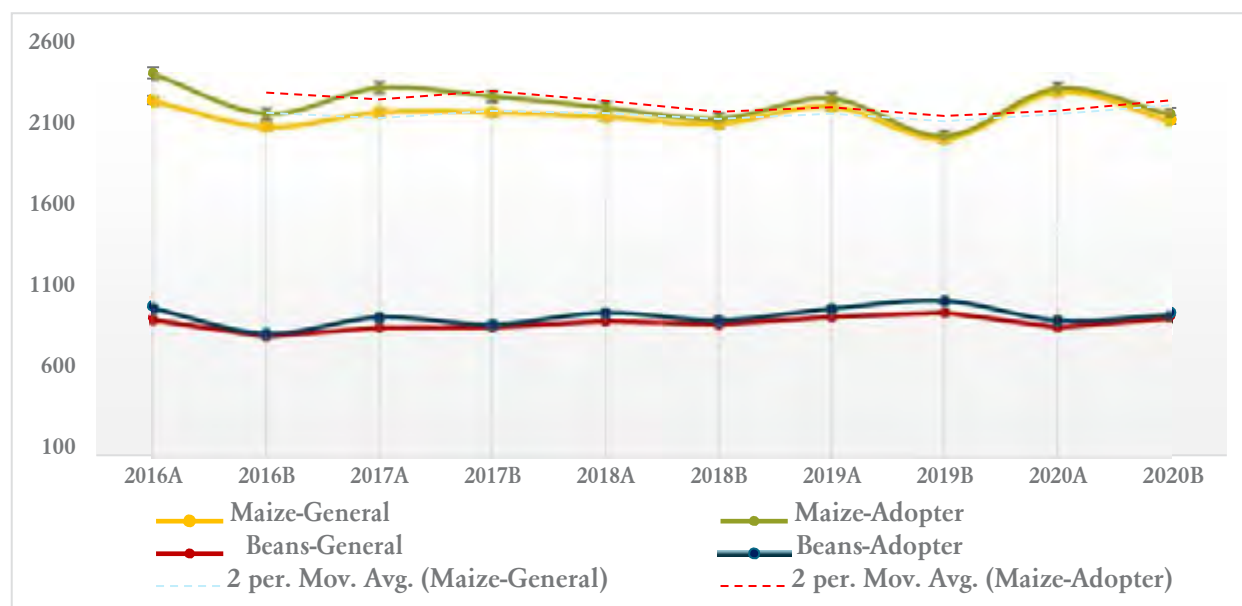


Figure 10: Trend of farmer yield for 2016 through 2020

#### Seasonal variations in yield for nonadopters and adopters

For both beans and maize, the evidence shows that the land allocation for production has stagnated at 0.5 ha for bean and 1.0 hectare for maize. Yields of beans for adopters have consistently remained above of Nonadopters (less than 900 kg/ha<sup>1</sup> and above 900 kg/ha<sup>1</sup> respectively). Under maize for any given year and season, production is higher for adopters than nonadopters (Table 23).

Table 23: Seasonal patterns in area allocation to crop production and yield

Season	Bean farmers				Maize farmers			
	Overall area & output		Farmer yield		Overall area & output		Farmer yield	
	Area planted	Output	Na-Yield	Ad-Yield	Area planted	Output	NA-Yield	Ad-Yield
2016A	0.515	497.697	830.262	1001.258	1.083	2790.02	1646.469	2409.390
2016B	0.480	415.083	811.250	850.558	0.992	2179.266	1849.752	2170.447
2017A	0.537	505.213	791.936	947.514	0.963	2305.079	1737.077	2326.709
2017B	0.500	483.850	864.697	904.651	0.905	2190.261	1917.710	2274.418
2018A	0.544	549.162	849.857	975.284	0.985	2215.967	1956.766	2207.116
2018B	0.500	471.731	873.985	929.859	0.989	2169.064	2018.036	2140.562
2019A	0.511	492.796	878.724	999.399	0.929	2193.179	2023.781	2261.606
2019B	0.500	513.326	876.805	1047.193	0.901	1882.395	1957.582	2036.974
2020A	0.546	490.401	834.344	928.772	0.980	2344.208	2200.215	2323.252
2020B	0.520	513.662	921.292	961.046	0.912	2034.519	1988.961	2163.336

Note: Area planted is measured in hectares, output (Kgs), and yield in kg/ha. Na denotes nonadopter while Ad denotes adopter.

Overall, the level of adoption of beans and maize technologies was high at 79 and 60 percent, respectively. Technological and consumer attributes were key drivers for technology adoption. The improved adoption levels are linked to increased output though the yield gap with potential yield is high which means productivity is still low. The reasons for lower yield include pests and diseases, high costs of inputs, limited accessibility of certified seed, variations in weather patterns and limited application of recommended agronomic practices by farmers. The three most common types of agricultural information accessed by the beans and maize farmers included agronomic practices, improved varieties, and postharvest practices, all of which were below 60 percent. Less than 10 percent received information related to markets, sustainable land use, climate adaptation and weather, yet these elements are critical for production.

### 3.4. Access to credit and commodity markets

#### 3.4.1 Farmer access to commodity markets



Sorting beans by variety for better prices and market

Results indicated that on average farmers accessed 1 to 3 types of commodity markets with farm gate as most dominant (81%) as indicated in Table 24. This indicates that farmers still have limited access to other markets that may offer higher prices. Farmers have therefore not maximised the commodity value chain approach especially in marketing, which compromises maximisation of their returns.

Government has placed efforts, where regional markets were established to bolster farmer access to markets. These markets include Hoima central market in Bunyoro sub region, Lira Central market, and Gulu central market among others. Results however, reveal that few farmers have accessed these regional markets and Kampala markets and the situation is same for nonadopters and adopter farmers. Much as the regional markets could offer a better price, they are often distant and not easy to access by an individual farmer (see distances in Table 24). Therefore, strategies should continue to support regional market approach to establish more markets. Warehousing should be prioritised to enhance marketing and pricing.

**Table 24: Markets accessed by farmers**

Variable	Proportion of farmers				
	Overall	Bean	Maize	Nonadopters	Adopters
Farm gate	0.812	0.792	0.836	0.755	0.840
Local trading market	0.172	0.185	0.157	0.237	0.141
Main district urban market	0.014	0.016	0.012	0.012	0.015
Main sub regional market	0.001	0.003	0.000	0.001	0.002
Kampala market	0.005	0.009	0.000	0.001	0.007

Note: Sub regional market are markets based on the sub regions in Uganda for instance Gulu district market which is a market hub for Acholi sub region. Others include Mbale market, Hoima, Arua, Jinja, Lira, etc.

#### Distance to markets

Overall, the distance from the farmer households where produce is often stored to output markets stands at an average of about 2 kilometres (Table 25). Since majority of farmers sell at the farmgate, it is averred that majority cover less than 0.01Km (>5 meters) to a point of exchange.

**Table 25: Distance to market**

Market place	Mean (Km)	SD	Min	Max	Bean	Maize	Other crops
Overall	1.910	12.201	0.000	360.00	2.948	1.052	1.007
Farm gate	0.008	0.052	0.000	0.500	0.012	0.007	0.001
Kampala	143.472	49.191	75.000	360.00	151	93.333	118.333
Local market	3.334	3.502	0.420	20.00	3.467	3.053	4.232
Main district market	20.547	22.744	0.500	100.00	20.72	20.551	19.500
Main regional	41.667	39.375	0.500	150.00	45.364	56.667	9.000

### 3.4.2 Farmer level commodity price trends

#### General price trend

The general trend of price offered to the farmers indicates there have not been significantly changes for both beans and maize. In the case of maize, the average price had only changed by about UGX 5 per kilogram, while that for bean farmers had registered an increase by UGX 276 from the 2016A price (Fig. 11).

**Figure 11: Seasonal farmer price trend**

#### Price by ZARDI

Considering the statistics over the four years, the prices have not significantly changed over the same period across all the ZARDIs (Table 26). Prices of maize and beans have been static over the years despite an observed increase in production. Farmers' margins have therefore not increased over time.

Table 26: Price variation along ZARDIs for bean and maize farmers (UGX per Kg)

Variable	Proportion of farmers					
	Bean farmers			Maize farmers		
	Overall	Nonadopters	Adopters	Overall	Nonadopters	Adopters
OVERALL	1945.487	1847.771	2012.774	621.826	610.635	624.963
ABIZARDI	2537.000	2474.074	2610.870	766.393	747.701	783.333
BUGIZARDI	2103.405	1956.364	2136.280	621.869	551.869	633.834
BUZARDI	1656.890	1623.711	1677.389	567.932	613.704	558.778
KAZARDI	1756.337	1653.563	2035.484	-	-	-
MUZARDI	1939.447	1964.740	1927.292	579.446	554.815	588.432
NGETA	1880.890	1752.586	1988.221	682.798	707.188	677.686

### 3.4.3. Bean and maize crop Utilisation

#### Crop Utilization

Smallholder farmers are traditionally known to only sell crop surplus after satisfying household food demand. However, with increasing output, the surplus may be greater than the consumed. Table 27 shows that on average, each bean-growing household produced about 489 kg in a season (2020A harvest) and 707 kg as annual output based on 2020 household production (Table 27). Farmers sold about 80 percent of the annual output. Maize farmers sold about 73 percent of produce. Most bean farmers sold 50 percent or more of the harvest while 87 percent of maize farmers sold 50 percent, and above which shows that the level of market participation is high among the smallholder farmers.

Table 27: Utilization of harvest

Variable	Mean	St. Dev.	Min	Max	Na	Ads.	P stat
<b>Beans</b>							
Seasonal production	488.929	906.94	2	15000	319.985	606.786	0.0001
Annual output 2020	706.499	1508.556	0	30000	509.58	836.698	0.0047
Quantity for HH	114.244	165.915	0	2620	98.683	124.533	0.0426
Quantity sold	592.255	1452.953	0	30000	410.897	712.165	0.0069
Share of bean harvest sold	0.798	0.152	0.5	1.000	0.791	0.800	0.4393
Farmers who sold $\geq 0.500$	1.000	0.000	1.0	1.000	1.000	1.000	-
<b>Maize</b>							
Seasonal production	2332.278	3417.547	50	40000	1598.22	2520.06	0.0056
Annual output 2020	2672.873	4017.967	0	43500	1802.834	2907.574	0.0022
Quantity for HH	432.095	718.176	0	7000	311.094	464.736	0.0173
Quantity sold	2240.778	3686.125	0	41800	1491.74	2442.838	0.0041
Share of maize harvest sold	0.728	0.254	0	1.000	0.660	0.746	0.0006
Farmers who sold $\geq 0.500$	0.873	0.333	0	1	0.809	0.890	0.0067

Note: All quantities are measured in Kgs while the share of crop to harvest is a proportion. Seasonal production estimate is based on 2020A harvest. Quantity consumed at home includes what is eaten, used for seed and any other purpose other than selling. Annual maize harvest is not necessarily twice the seasonal harvest because most households under the study grew maize once a year.

### Comparison of bean and maize crop income

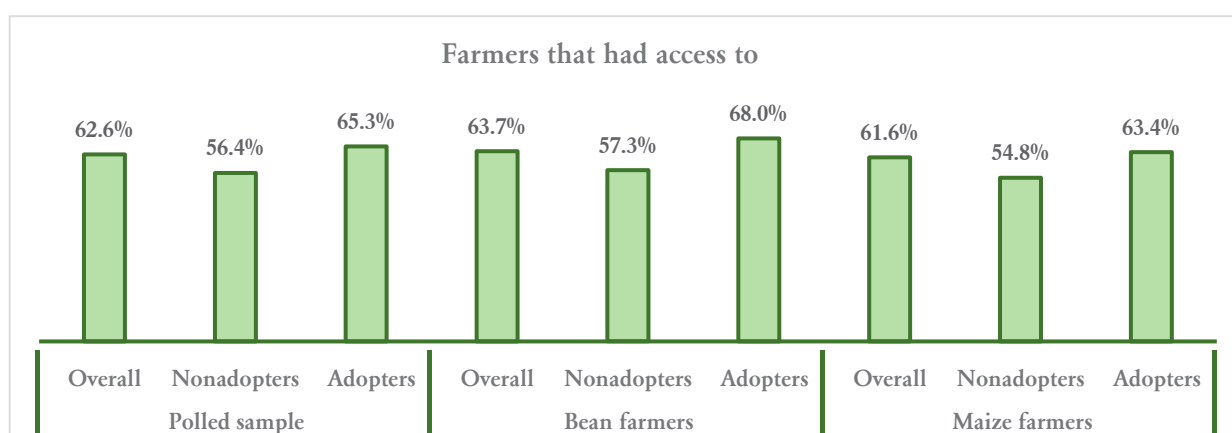
Results (Table 28) show that there was a significant difference in price and revenue from sale of beans for adopters and non-adopters of NARO bean technologies. The bean incomes were at UGX 0.5 million and UGX 1.0 million for non-adopters and adopters respectively. This implies that the difference may be partly a function of the prices and not quantities sold. FGDs indicated clear price differences for the bean varieties due to their different attributes. The maize incomes were UGX 0.7 million and UGX 2.0 million for non-adopter and adopter maize farmers respectively, the difference was due to quantities produced rather than price. Efforts are further needed in generating maize varieties of even shorter maturity period than the current one to enable farmers plant twice in a year.

**Table 28: Bean and maize income gap between nonadopters and adopters**

Variable	Means (UGX)				P stat.
	Nonadopter	Std. Dev.	Adopters	Std. Dev.	
<b>Beans</b>					
Price of beans per Kg (in UGX)	1847.771	567.874	2012.774	597.97	0.0000
Value of bean harvest (UGX)	599000.00	748000	1270000	2420000	0.0000
Proportion sold	0.805	0.177	0.81	0.155	0.3427
Revenue from bean sales	481,000	661,000	1,090,000	2,310,000	0.0000
<b>Maize</b>					
Price of maize per Kg (in UGX)	610.635	178.581	624.963	179.609	0.0804
Value of maize harvest (UGX)	886000	1430000	1550000	2490000	0.0000
Proportion sold	0.695	0.296	0.778	0.227	0.0000
Revenue from maize sales	759,000	1380000	1,300,000	2050000	0.0000

#### 3.4.4 Access to credit

Access to production finance is critical for farmers to enable farmers acquire inputs in the production cycle.



### Figure 12: Proportion of farmers with access to credit

Overall, it was observed that 63 percent of farmers indicated they had access to credit. The percentage for adopters (65%) was higher compared to non-adopters (56%). This pattern was the same between bean and maize farmers (Fig. 12).

Farmers accessed credit services from various informal and formal sources. Table 32 indicates that informal savings scheme was the highest source of credit at 39% for adopters and 32% for non-adopters. Twenty percent (20%) adopters and 17% non-adopters accessed SACCOs as a source of credit. A similar trend was observed between maize and bean farmers. Very few farmers accessed credit from government credit scheme and banks. Government should endeavour to increase farmers' access to credit through its popular programmes such as "emyooga" and farmer focussed credits in commercial banks. Given that smallholder farmers accessed small credits, government should create a bank for them with similar arrangements as Uganda Development Bank, where large scale farmers access large credits. Government should also strengthen SACCOs to improve access to credit by smallholder farmers. The approach of Parish Development Model (PDM) by government is expected to increase access to credit.

Table 29: Sources of credit

Variable	Proportion of farmers						
	Pooled sample	Overall		Bean farmers		Maize farmers	
		Na.	Ad.	Na.	Ad.	Na.	Ad.
Employer	0.002	0.000	0.003	0.000	0.000	0.000	0.005
Relative/ friend	0.029	0.037	0.026	0.039	0.026	0.032	0.026
Informal savings scheme	0.368	0.317	0.390	0.331	0.381	0.293	0.397
Money lender	0.014	0.014	0.014	0.014	0.009	0.013	0.017
Gov't credit scheme	0.006	0.002	0.008	0.004	0.007	0.000	0.009
SACCO	0.193	0.169	0.204	0.189	0.238	0.134	0.179
NGO	0.008	0.009	0.008	0.007	0.019	0.013	0.000
FBO	0.002	0.000	0.003	0.000	0.002	0.000	0.003
Bank or DFI	0.070	0.057	0.075	0.050	0.075	0.070	0.076
MFI	0.020	0.021	0.020	0.021	0.014	0.019	0.024
Other source	0.030	0.032	0.029	0.032	0.031	0.032	0.027

### 3.5 Household income

Income is one of the measures of household welfare and it typically accrued from sales of various crops, livestock and its products, liquidated assets, and remittances. In this study, total household income was computed from the various income sources. This was relevant in the sense that it informs progress of rural households towards national goal of each household earning more than USD 1000 per annum as an indicator of being in the lower-middle income bracket.

### 3.5.1 Income from farm and nonfarm activities

#### Sources of household income

In this section income from farm activities including beans, maize, other crops, livestock and livestock products, and income from nonfarm activities are estimated. Table 30 shows the percentage of farmers per income source; the respective income estimates are presented in Table 31.

**Table 30: Percent of farmers per income source**

Income source	Percent of farmers						
	Overall (N=1445)			Nonadopters		Adopters	
	2020	2016	P stat.	2020	2016	2020	2016
Other crops income	79.0	-	-	78.8	-	79.2	-
Livestock income	75.7	46.9	0.0000	73.3	43.4	76.8	48.4
Livestock products income	23.6	13.0	0.0000	23.1	11.6	23.8	13.6
Nonfarm income	44.2	30.3	0.0000	38.4	26.9	46.7	31.8

Note: Data on other crops (2016) was not captured

Most of the farmers owned the small livestock type (in 2020) including goats (38%) followed by chickens (38%) and pigs (29%) (Annex 10). Though the percentage of farmers was lower, the ownership pattern in terms of type of livestock owned was same in 2016. Additionally, the most sold livestock products include cattle and milk (Annex 11).

#### Household income

Table 31 presents results on total household income generated from various sources including income from beans/maize, other crop income, livestock sales, income from livestock products (such as milk, eggs, hides, etc.), and nonfarm income. Generally, the household income of 2020 is higher than 2016. From the statistics, it emerges that the general average household income is about UGX 5.6 million in 2020 compared to UGX 2.46 million in 2016. In 2020 the contribution of farm income to total household income is approximated at 78.5 percent while the rest was from nonfarm income.

**Table 31: Overall household income**

Income source	Overall mean household income (UGX)							
	Mean	2020			Mean	2016		
		SD	Min	Max		SD	Min	Max
Beans/Maize	1270000	2290000	0	31,500,000	557000	2240000	0	42,500,000
Other crops	1400000	2240000	0	28,300,000	-	-	-	-
Livestock	664000	1900000	0	30,000,000	465000	1950000	0	32,000,000
Livestock products	453000	3620000	0	92,200,000	148000	816000	0	15,100,000
<b>Total farm income</b>	<b>3790000</b>	<b>5780000</b>	<b>0</b>	<b>97,700,000</b>	<b>1170000</b>	<b>3520000</b>	<b>0</b>	<b>45,400,000</b>
Nonfarm income	1830000	4300000	0	63,600,000	1290000	3820000	0	36,400,000

Note: UGX means Uganda shillings and HH means household

Table 32 shows that bean farmers earned about UGX 5.45 million while maize farmers earned about 5.79 million and the contribution of farm income to total household income for bean farmers was approximately 78 percent similar to that for maize farmers at 79 percent.

**Table 32: Income of bean and maize farmers**

Income source	Mean household income (UGX)							
	2020				2016			
	Mean	SD	Min	Max	Mean	SD	Min	Max
<b>Bean farmers</b>								
Bean income	1180000	2360000	0	31,500,000	419000	2230000	0	42,500,000
Other crops	1250000	1930000	0	16,300,000	-	-	-	-
Livestock	669000	1970000	0	30,000,000	554000	2290000	0	32,000,000
Livestock products	513000	3520000	0	72,000,000	157000	931000	0	15,100,000
Total farm income	3610000	5620000	0	74,500,000	1130000	3810000	0	45,400,000
Nonfarm income	1840000	4890000	0	63,600,000	1240000	3840000	0	36,000,000
Total HH income	5,450,000	8,330,000	0	103,000,000	2,370,000	6,050,000	0	81,400,000
<b>Maize farmers</b>								
Maize income	1360000	2220000	0	24,900,000	688000	2250000	0	40,800,000
Other crops	1550000	2500000	0	28,300,000	-	-	-	-
Livestock	659000	1820000	0	30,000,000	380000	1560000	0	32,000,000
Livestock products	396000	3720000	0	92,200,000	139000	688000	0	10,400,000
Total farm income	3970000	5930000	0	97,700,000	1210000	3230000	0	44,400,000
Nonfarm income	1820000	3660000	0	36,000,000	1330000	3800000	0	36,400,000
Total HH income	5,790,000	7660000	0	98,000,000	2,540,000	5,440,000	0	44,600,000

#### Comparison of household income of adopter and non-adopter of bean/maize technologies

Considering 2020 income, overall household income of technology adopters is significantly higher (by about 34%) than that of the non-adopters (Table 33). However, when disaggregated by bean/maize farmer, the difference in household income between non-adopters and adopters was statistically not different for bean farmers. The difference in household income was statistically different for the maize farmers though still, considering only farm income for non-adopters and adopters.

**Table 33: Household income of non-adopters and adopters**

Variable	Mean household income (UGX)						
	2020			2016			
	Nonadopters	Adopters	P stat	Nonadopters	Adopters	P stat	
Overall total household income	4,550,000	6,090,000	0.0008	2,010,000	2,660,000	0.0481	
<b>Bean farmer</b>							
Farm income	3,070,000	3,960,000	0.0375	916,000	1,270,000	0.2264	
Nonfarm income	1,750,000	1,900,000	0.6848	1,170,000	1,290,000	0.6743	
Total HH income	4,820,000	5,870,000	0.1009	2,080,000	2,560,000	0.3031	
<b>Maize farmer</b>							
Farm income	2,720,000	4,300,000	0.0030	697,000	1,340,000	0.0255	
Nonfarm income	1,360,000	1,950,000	0.0742	1,170,000	1,380,000	0.5392	
Total HH income	4,080,000	6,250,000	0.0016	1,860,000	2,720,000	0.0794	

### Contribution beans and maize to total farm and household income

In Table 34, the contribution of bean/maize income to farm and household income is illustrated. Results show that the share of bean and maize income to (2020) farm income is about 41 percent and 36 percent, respectively, for non-adopters and about 42 percent for adopters of either bean or maize technology. Additionally, the contribution of bean and maize income to household income ranged between 27% and 34 percent. These results indicate that most households were highly dependent on bean and maize farming for household income.

**Table 34: Share of bean and maize income to farm and household income**

Variable	Mean (Proportion)							
	Bean farmers				Maize farmers			
	2020		2016		2020		2016	
	Na.	Ad.	Na.	Ad.	Na.	Ad.	Na.	Ad.
Share of farm income to household income	0.792	0.777	.659	0.648	.824	.778	.672	.613
Share of bean/maize income to farm	0.407	0.418	.500	0.434	.357	.417	.473	.491
Share of bean/maize income to HH income	0.328	0.338	.305	0.271	.296	.332	.320	.318

### 3.6. Household food security

This section presents holistic analysis of food security among adopters and non-adopter households of NARO bean and maize technologies. The following sub-sections are outlined: Food security situation in Uganda; quality of household food consumption based on Household Dietary Diversity (HDD) measure and prevalence of household food insecurity in Uganda. It also outlines household food consumption grades, per capita consumption of maize and beans in Uganda, the contribution of beans and maize to energy intake and factors that influence food security among technology adopters and non-adopters.

#### 3.6.1 Food security in Uganda

According to FAO (2009), food and nutrition security exists when all people, at all times, have physical, social and economic access to food consumed in adequate quantity and quality to meet their dietary needs and food preferences. Based on FAO, food security is described as a 4-tier paradigm involving availability, access, utilization, and stability (FAO, 2016). These four pillars are expected to be supported by an environment of adequate sanitation, health services and care for a healthy and active population. This integrated definition facilitates decision-making and actions that support eradication of global hunger and malnutrition in accordance with the SDG agenda.

Despite the national emphasis on achieving food security and adequate nutrition for good health, social and economic wellbeing, Uganda faces some pockets of food insecurity and undernutrition. The collaborative study on food security in 2020 using Integrated Food Security Phase Classification (IPC) protocols indicated that about 40 percent of the population analysed were food secure (phase 1) (IPC, 2021). While an estimated 2.6 million people (23%) experienced acute food insecurity (phase 3 or

above), of whom 17 percent and about 5 percent were in crisis and emergency respectively. The study projected a decrease in share of the population experiencing acute food insecurity between the periods of September 2020 to January 2021. Within the same period, the share of population that was experiencing minimal food insecurity (phase 1) was expected to decrease, implying improvement in food security status.

### 3.6.2 Household food security based on food consumption

#### Number of meals

The number of meals eaten by a typical household may range from 1 to 5 including breakfast, lunch, dinner, and snacks. In Table 35, number of meals taken in households is presented. Results show that households mainly consumed 3 meals in a typical 24-hour day regardless of type of farmer by enterprise or technology adoption. During lean seasons, the number of meals reduced to an average of 2. This is typical of rural household behaviour where daytime is most spent on the farm.

**Table 35: Number of meals**

Variable	Mean of number of meals consumed at household level					
	<u>Pooled sample</u>	<u>Farmer by crop</u>		<u>Farmer category</u>		
	Mean	Bean	Maize	Nonadopter	Adopter	P stat.
Meals eaten in the prev. day	2.775 (0.494)	2.766	2.783	2.733	2.793	0.0320
Meals eaten in lean period	2.356 (0.676)	2.340	2.371	2.331	2.366	0.3604
Meals eaten in a bumper period	2.887 (0.547)	2.867	2.907	2.886	2.888	0.9506

Note: Values in parenthesis are standard deviations

#### Nature of household weekly diet

The exact make-up of a healthy diet varies depending on individual characteristics, cultural context, local availability of foods and dietary customs, but the basic principles of what constitutes a healthy diet remain the same (FAO, IFAD, UNICEF, WFP, & WHO, 2020).

Results in Table 36 indicate that few households consumed each of the nine foods groups comprised of starch, pulses, meat, vegetables, oil, fruits, milk, sugar, and condiments in the last 7 days. The seven-day food group consumption was higher for staples, sugars, condiments, and pulses while very low for fish, eggs, and vitamin A rich foods. Meat is mainly eaten during the first two days of the week. The results indicate evidence of limited household diet diversity within the study period and thus, the households could be vulnerable to hidden hunger (Table 36). Households tend to eat more food items of staples, sweets and sugars, condiments, spices, and beverages and fats and oils on Sundays when they are resting from on farm activities.

**Table 36: Weekly household food consumption**

Food group [Number of days >>]	Proportion of households								
	0	1	2	3	4	5	6	7	
Cereals	0.080	0.111	0.172	0.138	0.113	0.084	0.073	0.228	
White roots & tubers	0.101	0.130	0.226	0.176	0.101	0.076	0.068	0.123	
Staples (cereals, roots, & tubers)	0.011	0.028	0.053	0.074	0.092	0.121	0.076	0.544	
Pulses (Legumes, nuts, and seeds)	0.041	0.064	0.132	0.143	0.115	0.118	0.116	0.271	
Dark green leafy vegetables	0.221	0.155	0.198	0.117	0.090	0.080	0.043	0.097	
Flesh meats	0.403	0.317	0.155	0.062	0.024	0.019	0.010	0.011	
Organ meat	0.827	0.102	0.032	0.013	0.009	0.008	0.004	0.004	
Milk & milk products	0.453	0.104	0.107	0.064	0.039	0.036	0.024	0.173	
Fish and sea foods	0.612	0.180	0.094	0.050	0.025	0.020	0.005	0.016	
Eggs	0.516	0.196	0.121	0.078	0.033	0.018	0.013	0.026	
Oils & fats	0.198	0.060	0.084	0.091	0.082	0.089	0.080	0.317	
Vitamin A rich vegetables & tubers	0.452	0.165	0.154	0.094	0.052	0.027	0.017	0.039	
Other vegetables	0.279	0.087	0.133	0.080	0.062	0.046	0.050	0.262	
Vitamin a rich fruit	0.462	0.158	0.137	0.075	0.051	0.031	0.016	0.071	
Other fruits	0.553	0.156	0.116	0.064	0.042	0.026	0.010	0.033	
Sweets & sugars	0.200	0.078	0.083	0.089	0.076	0.060	0.068	0.357	
Condiments, spices, & beverages*	0.376	0.084	0.061	0.062	0.038	0.033	0.028	0.318	

Note: Household food consumption is in the context of past 7 days recall, Column 0 presents those who did not consume the food item, and \*includes salt, soft beverages, and alcohol drinks.

### Household food consumption by adopters and nonadopters

The 17 food categories (in Table 36) were condensed to 9 as recommended by WFP/FAO guideline on diet diversity requirement. The analysis is a useful indicator of calorific sufficiency as it is a proxy for quantity dimension of food security that is energy intake and both macro and micronutrients (WFP, 2016). Table 37 presents information on different food types consumed by bean and maize farming households within the context of seven days. The results also compared food consumption by the adopters and nonadopters.

The results generally showed that there were no significant differences in consumption of the recommended food types by households growing beans and maize, whether adopters and nonadopters with an average number of days above five for staples and vegetables (Table 37). This pattern is closely followed by pulses, sugars and; oils and fats. These are the major food items that were eaten in the farming communities.

Table 37: Foods eaten in last 7 days by adopters and nonadopters of improved technologies

Food group	Mean number of days household consumed the food								
	Overall	Beans	Maize	Na.	Ad.	Beans		Maize	
						Na.	Ad.	Na.	Ad.
Staples	5.60	5.56	5.63	5.42	5.67	5.57	5.56	5.14	5.76
Pulses/ legumes	4.40	4.64	4.17	4.61	4.32	4.91	4.47	4.06	4.20
Vegetables	5.04	4.93	5.15	4.79	5.15	4.73	5.06	4.91	5.21
Meats & eggs	2.97	2.83	3.10	2.71	3.08	2.58	3.00	2.94	3.14
Milk/milk products	2.20	2.01	2.39	1.68	2.43	1.46	2.37	2.08	2.47
Fruits	2.64	2.61	2.66	2.35	2.76	2.23	2.86	2.56	2.69
Sugars	3.96	3.78	4.13	3.34	4.23	2.89	4.36	4.14	4.13
Oils & fats	3.97	3.70	4.24	3.33	4.25	3.05	4.12	3.84	4.34
Condiments	3.10	2.91	3.28	2.71	3.27	2.39	3.26	3.3	3.27

Note: Na denotes nonadopters while Ad denotes all adopters; Na denotes nonadopters. Condiments....

### 3.6.3 Prevalence of household food insecurity

Prevalence of food security was estimated using the food consumption score (FCS) approach; FCS was used as a proxy indicator for household food security and relative nutritional importance of food groups to adopters and nonadopters. Results are presented in Figure 13, overall, 72 percent of the surveyed households had acceptable food consumption status, thus considered food secure. Adopter households were more food secure (76%) compared to the nonadopters (63%). This indicates the contribution of NARO technologies to food security.

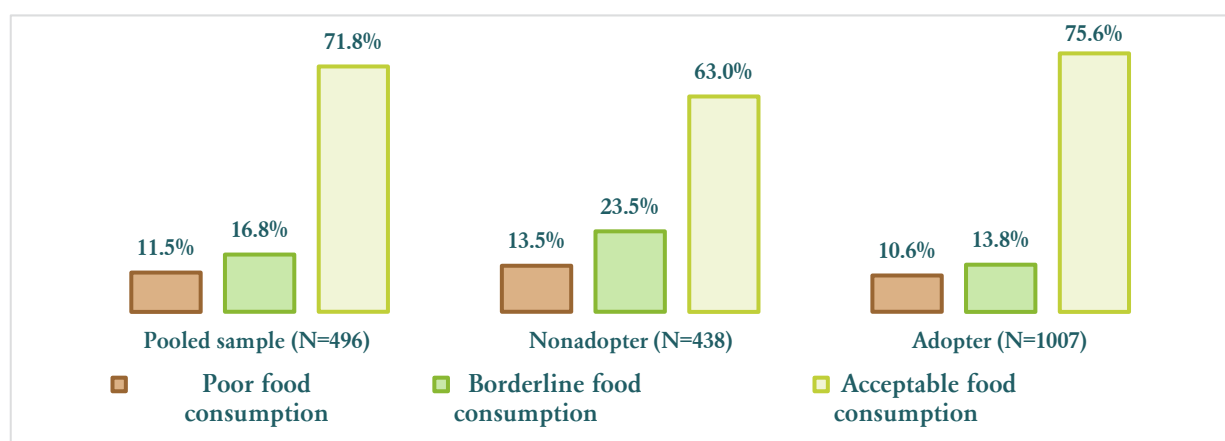


Figure 13: Household food consumption grades

### Food security status per ZARDI

Overall, farmers in BUZARDI had the highest percentage (87%) of households found to be food secure followed by Buginyanya zone (85%) and Mukono zone at 79% (Table 38). This pattern is mirrored for nonadopters and adopters. This is explained by the favourable agro-ecological characteristics of these zones such as high and well-distributed rainfall with two seasons of farming, and good soils.

KAZARDI and ABIZARDI had a low food security record (45%) and more so among the nonadopters in relation to their counter parts. For KAZARDI, the situation was explained by lack of diverse crops and limited access and choice of foodstuffs. The land area is also highly fragmented due to a high population density that makes it difficult for a given household to allocate enough land to staple foodstuffs. In ABIZARDI, the low food security was attributed to small and non-arable land. In addition, rural urban migration, and engagement of male youth in boda-boda business leaves less productive farm labour that results in low production and subsequent food insecurity. The data also show that the percentage of food secure households of adopter households is significantly higher than the percentage of nonadopter households for most of the zones. This indicates that technology adoption has a potential of increasing household food security.

**Table 38: Household food security per ZARDI**

Zone	Percent of food secure households					
	Overall	Nonadopter	Adopter	P stat.	Bean farmers	Maize farmers
OVERALL	71.8	63.0	75.6	0.000	69.1	74.3
ABIZARDI	45.2	45.5	45.0		50.0	40.4
BUGIZARDI	84.7	70.6	87.3		60.7	82.6
BUZARDI	87.6	92.0	86.3		88.9	-
KAZARDI	45.1	42.5	51.7		42.5	-
MUZARDI	78.8	76.1	79.8		74.3	78.3
NGETTA	64.6	69.6	62.7		69.4	70.0

Note: lower-level disaggregation within crop and gender is not possible due to sample size problem

### Diet diversity and food security

Figure 13 relates diversity and food security among households. Households consuming three or less of the food categories are food insecure indicated by about 62 percent for poor food consumption. About 37 percent are categorised as food insecure on borderline. Seventy-eight households that fall under the acceptable food consumption are associated with eating four or more food categories. It is observed that households found to be food secure are associated with higher diet diversity meaning they have a higher energy intake and thus, better access to food in adequate amounts and acceptable quality in terms of diversity.

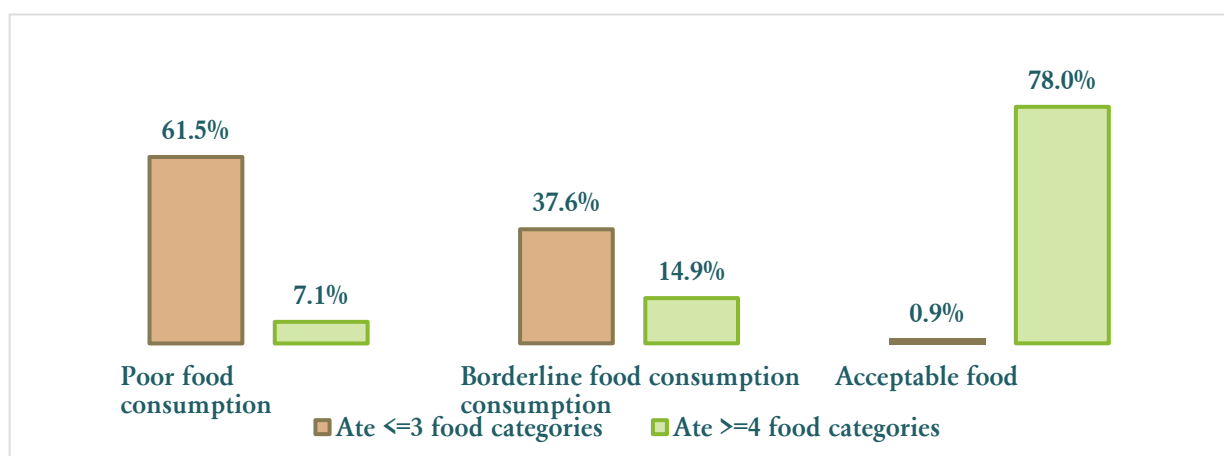


Figure 14: Food security and diet diversity

### 3.6.4 Contribution of beans and maize to food energy intake

#### Extent of bean and maize consumption

About 74 percent and 76 percent of farming households consumed beans and maize in 2 to 3 days of the week respectively (Table 39). For the rest of the days in the week, consumption was low indicating substitution with other foods.

Table 39: Weekly household consumption of beans and maize

Number of days	Proportion of respondents/ farmers					
	Bean farmers			Maize farmers		
	Overall	Nonadopters	Adopters	Overall	Nonadopters	Adopters
0 days	0.109	0.096	0.114	0.125	0.123	0.126
1	0.029	0.027	0.030	0.048	0.059	0.043
2	0.403	0.406	0.401	0.412	0.413	0.411
3	0.341	0.326	0.348	0.345	0.324	0.355
4	0.024	0.030	0.021	0.012	0.021	0.008
5	0.042	0.043	0.042	0.037	0.039	0.036
6	0.012	0.014	0.011	0.006	0.005	0.007
7 days	0.041	0.057	0.034	0.015	0.016	0.015

#### Contribution of beans and maize to energy intake

Globally, the share of dietary energy supplied by cereals is over 50 percent while the other foods contribute less of 50 percent. Maize followed by wheat are the top cereals in terms of production and consumption (OECD, 2020). In Uganda, staple food consumption differs by ethnic sub-regional groupings and urbanization with Central region eating more of cooking type banana while Northern gets most of its energy from cassava and sorghum. An adult need about 2 kg of food and water per day, which provides dietary energy of about 2000 kcal or 8400 kJ. According to WHO, an active female

adult ( $\geq 14$  years) requires about 2000 calories per day while an active adult male requires about 2500 calories per day. The evidence from the study showed that beans and maize combined contributed about 43 percent and 53 percent to female and male energy intake, respectively (Table 40).



Maize being dried for household food and market

Table 40 shows results on per capita consumption and the contribution of beans and maize to energy intake. Various bean varieties have different calorie content but on average, kidney beans cooked from dry form contain about 127 calories for every 100 grams. According to (CASA, 2020), the per capita bean consumption is about 52 kg and further shows that bean consumption provides 25 percent of the total dietary calorie intake and 45 percent of the protein intake. According to WHO, an active female adult ( $\geq 14$  years) requires about 2000 calories per day while an active adult male requires about 2500 kilo calories per day. The results (Table 40) show that the contribution of bean consumption to this required calorie intake is 27 percent for women and 22 percent for the men while maize contributes 26 and 21 percent for women and men, respectively. The evidence shows that beans and maize combined contribute about 53 percent and 43 percent to required energy intake of women and men, respectively.

**Table 40: Quantity of beans and maize consumed**

Variable	Mean	Std. Dev.	Min	Max
<b>Beans</b>				
Estimated annual per capita consumption (kg/person)	52.603	31.399	0	144.000
Estimated daily consumption per person (g)	144.117	86.026	0	394.521
Estimated daily calorie intake from beans (per person)	549.084	327.758	0	1503.123
Daily share of dietary energy from beans- adult female	0.275	0.164	0	0.752
Daily share of dietary energy from beans – adult male	0.220	0.131	0	0.601
<b>Maize</b>				
Estimated annual per capita consumption (kg/person)	49.486	33.877	0	173.333
Estimated daily consumption per person (g)	135.578	92.815	0	474.886
Estimated daily calorie intake from maize (per person)	516.552	353.625	0	1809.315
Daily share of dietary energy from maize- adult female	0.258	0.177	0	0.905
Daily share of dietary energy from maize – adult male	0.207	0.141	0	0.724
Est. daily energy intake from beans and maize (kcal)	1065.636	571.904	0	3075.836
Share of both beans and maize to energy intake- female	0.533	0.286	0	1.538
Share of both beans and maize to energy intake- male	0.426	0.229	0	1.230

Additionally, the results (in Table 41) reveal that energy contribution of beans and maize to the adopters of the improved technologies (58%) was slightly higher compared to the contribution to energy intake for nonadopters (55%).

**Table 41: Calorie contribution of beans and maize by farmer category**

Variable	Mean calorie contribution			
	Nonadopters		Adopters	
Est. daily energy intake from beans and maize (kcal)	1106.994	(567.44)	1158.597	(551.6)
Share of both beans and maize to energy intake-	0.553	(0.284)	0.579	(0.276)
Share of both beans and maize to energy intake- male	0.443	(0.227)	0.463	(0.221)

Note: Values in parenthesis are standard deviations

### 3.6.5 Household food access and food insecurity

Using the Household Food Insecurity Access scale (HHFIAS), the four parameters of food access indicators were assessed namely Household food insecurity access-related conditions, household food insecurity domains, food insecurity scale score, and prevalence of household food insecurity. Generally, many households employ multiple strategies to access food and this approach enables them to reduce food expenses and avert food insecurity including its related health consequences (IFPRI, 2009). To comprehensively understand household food availability and access, this impact study sought out information on food acquisition strategies.

#### Food access

Households make food available through various mechanisms namely own food production and stocks and purchases. Food availability refers to the physical existence of food at household level and

on a national level; food availability combines domestic food production, commercial food imports and exports, food aid and domestic food stocks.

Generally, many households employ multiple strategies to access food and this approach enables them to reduce food expenses and avert food insecurity including its related health consequences (IFPRI, 2009). To comprehensively understand household food availability and access, this impact study sought out information on food acquisition strategies. The results in Figure 15 show that majority (61%) of the households obtained food through own production. About 44 percent of the households did food purchases of some foods from markets. This implies that whilst a significant percentage of households rely on own production, many also purchase food. In the event of food price shocks, however, households that solely depend on food purchases can become vulnerable to food insecurity. These results are in line with other findings where about 89 percent of Uganda's population is indicated to be food secure with normal access to food from own production and markets (FAO, 2022).

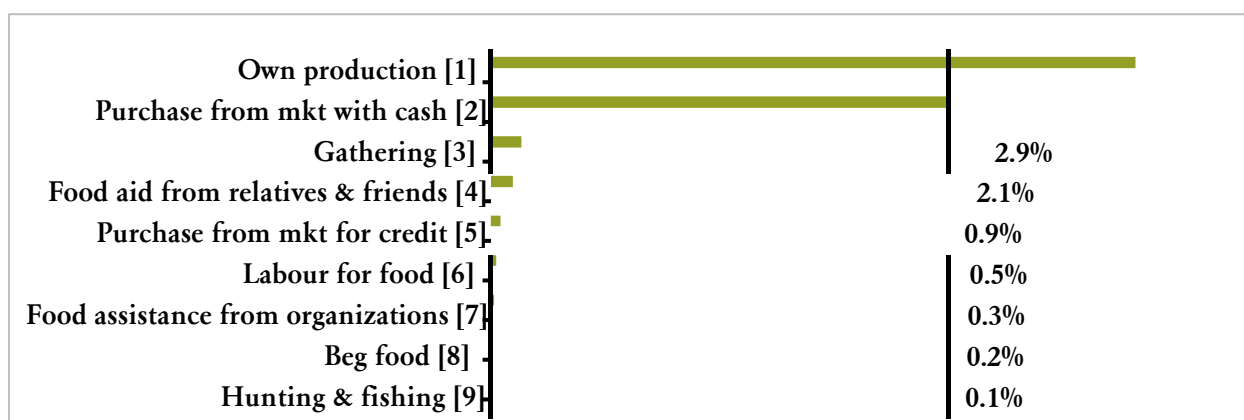


Figure 15: Household food sources

### Household food stability

Food access is the spatial affordability and right to avail food in a desired period whereas food stability refers to the ability of the household/individual to obtain food over time. Food stability can be affected by factors like weather and price shocks, and political instability leading to food shortage in a specified period. Household food shortage depends on several factors namely household exposure to weather, social, political, and economic shocks.

### Long haul household food stability

Under food shortage, the study focused on a long-haul period of the past 12 months prior to the study. Generally, about 35 percent of the farmers reported that they had experienced some food shortages in the past 12 months (Feb 2020 to Feb 2021). About 40 percent nonadopter households reported food shortage compared to 30 percent adopter households (Fig. 16). This was reported to occur during the planting period when food reserves tend to drop. The percentage of farmers who reported food shortages was generally higher among nonadopters compared to the adopter farmers.

The low food shortage among adopters may be partly associated with higher production of both beans and maize food crops that are contextualized in this study and are grains with a possibility of a long shelf life when well managed postharvest.

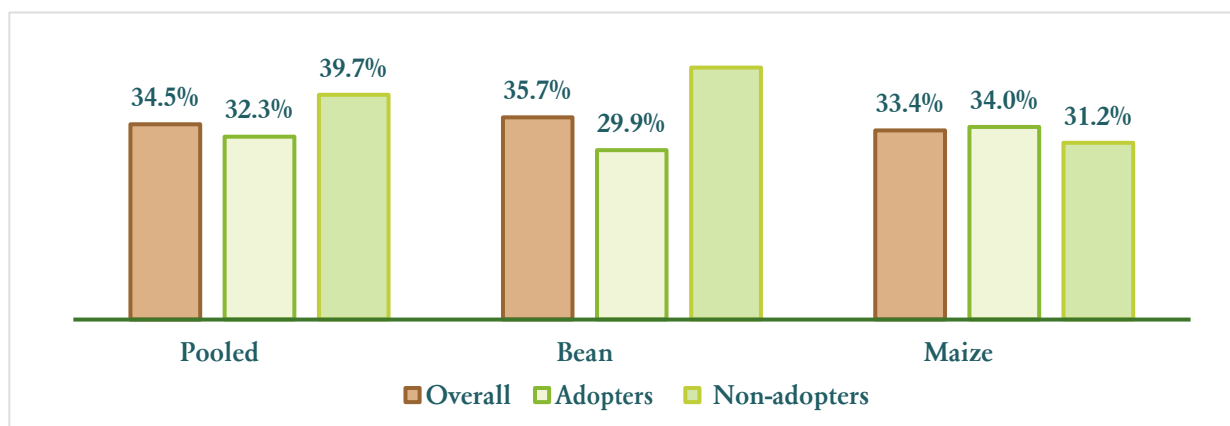


Figure 16: Proportion of households that experienced food shortage

In Table 42, the highest percentage of households reporting annual food shortages was found to be in the (3) months of April to June which generally corresponds with the period of lean food stocks in most parts of Uganda following the crop production cycles (seasons). This observation was generally the same across bean and maize farmers. However, save for quarter of the year (Jan-March), the proportion of households suffering food shortage are seen to be a bit higher among nonadopters compared to adopters of NARO technologies for rest of the months in a calendar.

Table 42: Long period food shortage – in a year's context

Month	Proportion of farmers							
	Overall (N=1445)	Bea n farmer	Maize farmer	FH household	MH household	Nonadopter	Adopters	P stat
January	0.031	0.037	0.026	0.038	0.029	0.032	0.031	0.906
February	0.028	0.031	0.026	0.035	0.027	0.025	0.030	0.623
March	0.046	0.044	0.047	0.035	0.049	0.048	0.045	0.785
April	0.129	0.154	0.106	0.140	0.126	0.167	0.113	0.005
May	0.178	0.169	0.187	0.178	0.178	0.199	0.169	0.173
June	0.176	0.160	0.191	0.156	0.181	0.208	0.162	0.035
July	0.055	0.045	0.065	0.061	0.054	0.059	0.054	0.661
August	0.031	0.025	0.037	0.045	0.027	0.032	0.031	0.906
September	0.019	0.024	0.015	0.016	0.020	0.023	0.018	0.530
October	0.026	0.041	0.011	0.019	0.027	0.041	0.019	0.014
November	0.028	0.048	0.008	0.029	0.027	0.053	0.017	0.000
December	0.012	0.011	0.014	0.010	0.013	0.016	0.011	0.426

Food secure months such as September, October, November and December were the time most crops were harvested including beans and maize. The above statement is in line with a result reported in Table 35, where 55 percent of the households have at least three meals a day during bumper period.

Across ZARDIs, results show that most households (66%) did not suffer any food shortage (Table 43). About 11 percent suffered food shortage for about 1 to 2 months, which likely fall within April and June. Table 47 further shows that the zones where more households reported food shortage were Ngetta, KAZARDI and Abi Zones. About 17.8% of households had food shortage in May with corresponding percentages of 17% and about 19% for bean and maize farmers respectively. These results suggest that there is more need for dissemination of production and post-harvest handling technologies to these zones to combat food shortages during some periods of the year. The other explanation would be that the households in these areas tend to sell their produce and leave little for home consumption or have little capacity to store food.

**Table 43: Number of months of food shortage**

Number of months	Proportion of households						
	OVERALL	ABIZ	BUGIZ	BUZ	KAZ	MUZ	NGEZ
0 months of food shortage	0.655	0.548	0.602	0.743	0.206	0.865	0.517
1	0.109	0.206	0.066	0.105	0.167	0.044	0.215
2	0.118	0.171	0.117	0.067	0.324	0.044	0.172
3	0.082	0.055	0.186	0.057	0.147	0.020	0.072
4	0.023	0.015	0.021	0.019	0.118	0.012	0.014
5	0.007	0.000	0.009	0.000	0.029	0.004	0.010
6	0.003	0.000	0.000	0.010	0.010	0.006	0.000
7	0.001	0.005	0.000	0.000	0.000	0.000	0.000
10	0.001	0.000	0.000	0.000	0.000	0.002	0.000
12 months of food shortage	0.001	0.000	0.000	0.000	0.000	0.002	0.000

#### Short haul household food shortage

Additionally, the short haul period of household food shortage, which looked at a seven-day, period shows that household vulnerability to food shortage in the shorter period is generally close to that of the long-haul analysis. Table 44 shows that about 18 percent of households reported food shortage in the week prior to the study. However, looking at specific areas, significant spikes in household food shortage are seen in some agricultural zones. KAZARDI area is found to have the highest percentage (40%) of households that reported food shortage followed by BUZARDI, BUGIZARDI and ABIZARDI. The results of BUZARDI are significantly different from other ZARDIs.

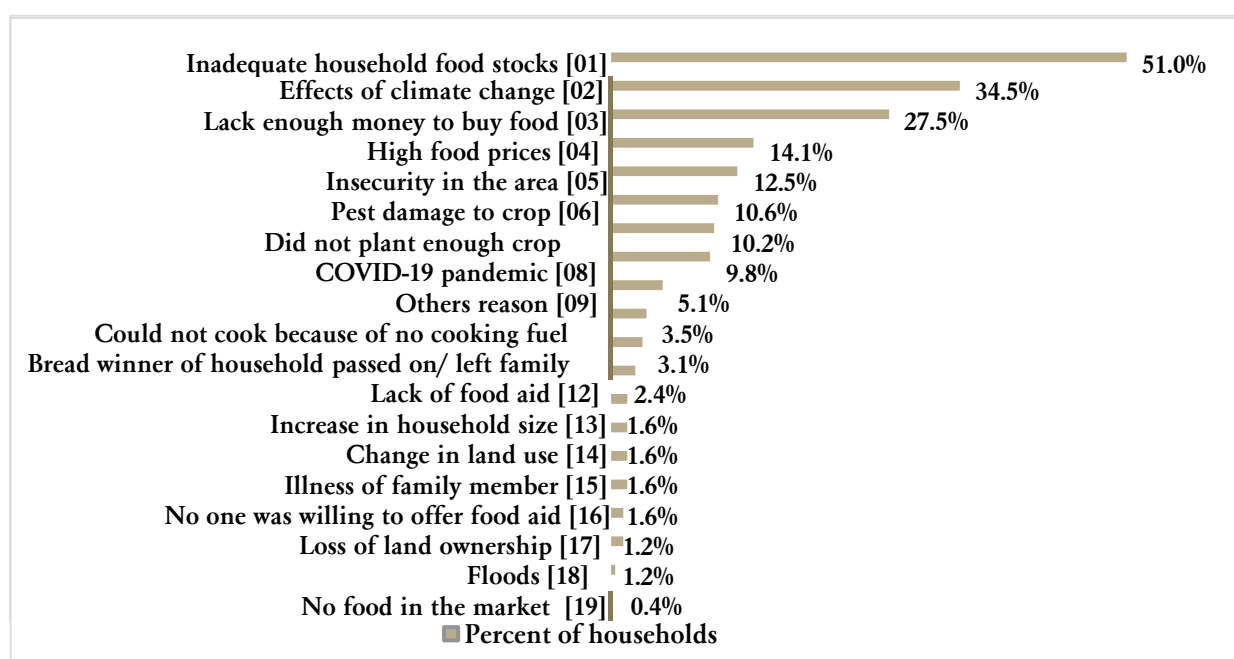
**Table 44: Short period food shortage**

Month	Proportion of farmers that had food shortage							
	Overall (N=1445)	Bea farmer	Maize farmer	FH household	MH household	Nonadopter	Adopters	P stat n
OVERALL	0.177	0.167	0.185	0.194	0.172	0.185	0.173	0.578
ABIZARDI	0.191	0.173	0.208	0.200	0.189	0.131	0.250	0.033
BUGIZARDI	0.192	0.162	0.212	0.181	0.195	0.235	0.184	0.389
BUZARDI	0.267	0.075	0.385	0.258	0.270	0.040	0.338	0.003
KAZARDI	0.402	0.402	-	0.538	0.355	0.479	0.207	0.011
MUZARDI	0.071	0.073	0.069	0.070	0.071	0.052	0.077	0.332
NGETTA	0.234	0.207	0.252	0.333	0.218	0.232	0.235	0.962

Note: the results are in context of the period: Sep to Oct 2021

### Reasons for food shortage

Results show that many of the households associated food shortage to limited food stocks (51%) and this was associated with the fact that most farmers in Uganda are engaged in subsistence agriculture (Fig. 17). The effect of climate change (a composite of drought, floods, and unpredictable rains) and lack of enough resource to access food came as other top reasons for short-run food shortages.

**Figure 17: Reason for food shortages**

In respect to inadequate food stocks, few farmers reserve food in small traditional granaries, others in the polythene bags in the house and improved stores (maize crib). These low-capacity storage facilities lead to less produce being stored and thus less food available for a long time.

For smallholder farmers the main purpose for storing grains is to ensure household food supplies and a form of saving to cover future cash need through sale. Maize grain is also stored for seed and as inputs into household enterprises such as beer brewing, or the preparation of cooked food. Although storage in silos would be the most appropriate in terms of storage pest management like weevils and rodents, it is still limited probably because of the high cost beyond the affordability of small-scale farmers.

#### Food access-related conditions

Food access conditions are conditions faced to access food namely totally having food in the household to a situation of having and eating some food for a day and a given situation may exacerbate household food security. In Table 45, about 26 percent of the households reported that they had no food in the house at some point in the past four weeks prior to the study (in Feb).

*“It’s not enough (food). We only have enough for the 3 months after harvest. The rest of the months are characterized by scarcity” (Men FGD 01 Bugi, Suam 14<sup>th</sup> Sep 2021)*

*Almost all the maize and beans produced in Sebei (Bukwo) is sold at the border to traders from Kenya. Some of them go into contract farming with the farmers and as soon as beans and maize are ready, its harvested, processed and taken to Kenya. [Men FGD 01 Bugi, Suam 14<sup>th</sup> Sep 2021]*

In the continuum of food insecurity conditions, it is also shown that 28 percent of the households were not able to eat preferred food while 26 percent ate some food, but which was not wanted (Table 45). The three conditions are the ones that prevailed most in both bean and maize farmers.

**Table 45: General Household Food Insecurity access-related conditions**

HH food insecurity condition	Proportion of households				
	Overall	Bean	Maize	FH HH	MH HH
1. Had no food to eat of any kind in your house	0.262	0.278	0.246	0.283	0.256
2. Went to sleep at night hungry without eating	0.042	0.050	0.035	0.061	0.037
3. Went a day & night without eating any food	0.030	0.034	0.027	0.038	0.028
4. Worried would not have enough food to eat	0.154	0.143	0.164	0.172	0.149
5. Was unable to eat the kinds of foods preferred	0.277	0.293	0.261	0.322	0.264
6. Had to eat a limited variety of food	0.243	0.256	0.230	0.264	0.237
7. Ate some foods that was not wanted	0.262	0.278	0.246	0.283	0.256
8. Ate smaller meal than felt needed	0.144	0.156	0.133	0.159	0.140
9. Ate fewer meals in a day	0.132	0.133	0.131	0.159	0.125

Note: FH HH denotes female headed household while MH HH denotes male headed household. May link to income

"...there are periods for example during the planting season when we buy food yet as farmers in the village, we are not supposed to buy food like people who live in towns." [Men FGD Bugi01, Suam, 14<sup>th</sup> Sept/2021]

"There are some foods that most men don't like to eat like cassava bread /atapa, posho, sweet potatoes and beans. It's not that they don't eat these foods, but they don't want to eat after taking local brew because they lose appetite for such foods" [Women FGD Bugi 02, Mutufu 15<sup>th</sup> Sept/2021]

"...for us (women), during the time of food scarcity, our main objective is to have food to eat and provide for the family. The issue of whether the food is wanted or not is not important at that time" (Women FGD Bugi 02, Tororo ,16<sup>th</sup> Sept/2021)

Table 46, summaries factors of food access related reasons, among adopters and non-adopters. About 30 percent of nonadopters were unable to eat preferred foods due to lack food or enough resources to access the food compared to 27 percent of the adopters. Among bean farmers, still, the percentage of farmers that were unable to access preferred foods was higher by 7 percent among nonadopter vis- a-vi adopter farming households. Under maize, adopter farmers experienced the condition of not eating preferred foods; 5 percent more compared to nonadopters.

**Table 46: Comparison of bean and maize farmers on access-related conditions**

Household situation	Percent of households					
	Pooled sample		Bean farmers		Maize farmers	
	Na.	Ad.	Na.	Ad.	Na	Adopter
Had no food of any kind to eat	0.281	0.253	0.331	0.242	0.191	0.261
Slept at night without eating food	0.057	0.036	0.068	0.038	0.038	0.034
Went a day & night with no food to eat	0.050	0.022	0.057	0.019	0.038	0.024
Worried would not have enough food	0.164	0.149	0.189	0.113	0.121	0.175
Unable to eat preferred kinds of foods	0.295	0.269	0.335	0.266	0.223	0.271
Had to eat a limited variety of food	0.263	0.234	0.295	0.231	0.204	0.237
Ate some foods that was not wanted	0.281	0.253	0.331	0.242	0.191	0.261
Ate smaller meal than felt needed	0.171	0.132	0.210	0.120	0.102	0.141
Ate fewer meals in a day	0.148	0.125	0.174	0.106	0.102	0.139

#### Household food insecurity indicator

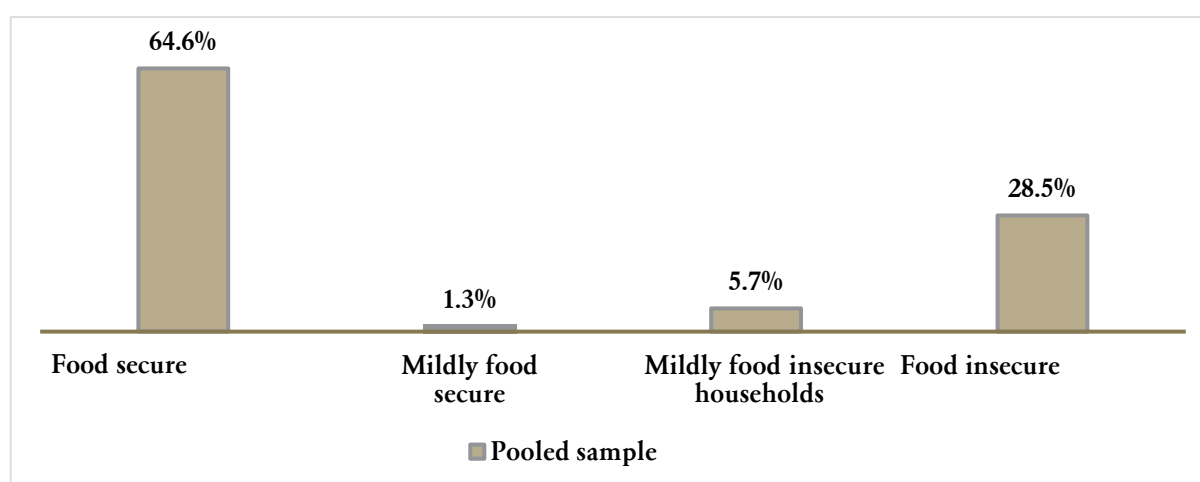
Household Food Insecurity Access indicator is derived from the sum of frequency of occurrence of the food access conditions (scale score). The indicator ranges from 0 to 27, as it tends to 1, the household is more food secure. KAZARDI had the highest mean compared to other agro-ecologies (Table 47). This observation may be due to lack of details on maize growing in KAZARDI as the zone does not significantly produce maize. Other ZARDIs had scores towards 1 indicating household food security.

**Table 47: Comparison of household food insecurity indicator at agro-ecologic level**

Zone	Mean score of HFIAS								
	Pooled sample	Bean farmers				Maize farmers			
		Overall	Na.	Ad.	P stat	Overall	Na.	Ad.	P stat
OVERALL	2.357 (4.079)	2.576	3.121	2.216	0.0062	2.147	1.975	2.194	0.5250
ABIZARDI	2.050 (3.716)	1.663	1.712	1.609	0.8721	2.426	2.000	2.796	0.3429
BUGIZARDI	1.380 (3.477)	0.978	1.143	0.935	0.7387	1.657	1.652	1.657	0.9953
BUZARDI	3.086 (4.007)	0.825	1.167	0.545	0.1693	4.477	1.857	4.793	0.0988
KAZARDI	7.284 (5.621)	7.284	7.123	7.690	0.6485	-	-	-	-
MUZARDI	1.986 (3.623)	2.335	1.784	2.569	0.1371	1.637	1.817	1.580	0.6401
NGETTA	2.321 (3.778)	2.049	2.306	1.848	0.6096	2.496	2.800	2.439	0.6857

### Household food insecurity prevalence

Results in Figure 18 show the general prevalence of food insecurity among the surveyed households. Overall, majority of the households were food secure and about 29 percent were food insecure. No significant differences in food (in)security status between non-intervention farmers/ households and the intervention farmers

**Figure 18: Food security status**

### Food security prevalence among non-adopters and adopters

Further scrutiny of food insecurity among adopters and non-adopters is shown in Table 48. Household food security status is comparable among adopters and non-adopters. Food insecurity is highest among non-adopters of beans at 36 percent compared to 29 percent among the adopters of maize. Generally, the prevalence of food insecurity is significantly higher among non-adopters vis-a- vi adopters for bean farming households.

**Table 48: Comparison of bean and maize farmers on level of household food security**

HH food security Status	Proportion of households						
	Pooled sample		P stat.	Bean farmers		Maize farmers	
	Nonadopters	Adopters		Nonadopters	Adopters	Nonadopter	Adopters
Food secure	0.626	0.654	0.2923	0.584	0.671	0.701	0.643
Mild food secure	0.016	0.011	0.4259	0.011	0.014	0.025	0.009
Mild food insecure	0.053	0.059	0.6465	0.046	0.054	0.064	0.062
Food insecure	0.306	0.276	0.2480	0.359	0.261	0.210	0.287

### Household coping strategies for food insecurity

Households adopt various strategies to cope with a food crisis in times of shocks. As another measure of food insecurity, coping strategy index can be a proxy indicator of household food insecurity. It relates to behaviours adopted by households facing food insecurity and allows for comparison across livelihood groups or regions. Table 49 illustrates these behaviours. In case of food shortages, households indulge in acquiring less preferred substitutes (31%), reduce the quantity and number of meals prepared and consumed by household members. This is observed among both non-adopters and adopters. On consumption of less preferred foods, a significant difference is noticeable between non-adopters and adopters.

**Table 49: Food insecurity coping strategies**

Coping strategy	Percent of households			P stat
	Pooled sample	Nonadopter	Adopters	
Substitute with less preferred	0.305	0.233	0.337	0.0001
Do nothing/stay hungry	0.022	0.030	0.019	0.2032
Rely on food aid	0.008	0.005	0.009	0.4311
Borrow from relatives/friends	0.059	0.069	0.055	0.2745
Work for food/money	0.150	0.140	0.155	0.5162
Reduce the number of meals	0.235	0.224	0.240	0.5240
Reduce quantity of food prepared	0.219	0.195	0.230	0.1372
Distress sales	0.004	0.009	0.002	
Other (Specify)	0.009	0.005	0.011	0.6657

### Priority household members during times of food insecurity

Generally, during times of food distress, children under five come as the top priority for the little food if any while the other household members may partake of the little food equitably (Fig. 19).

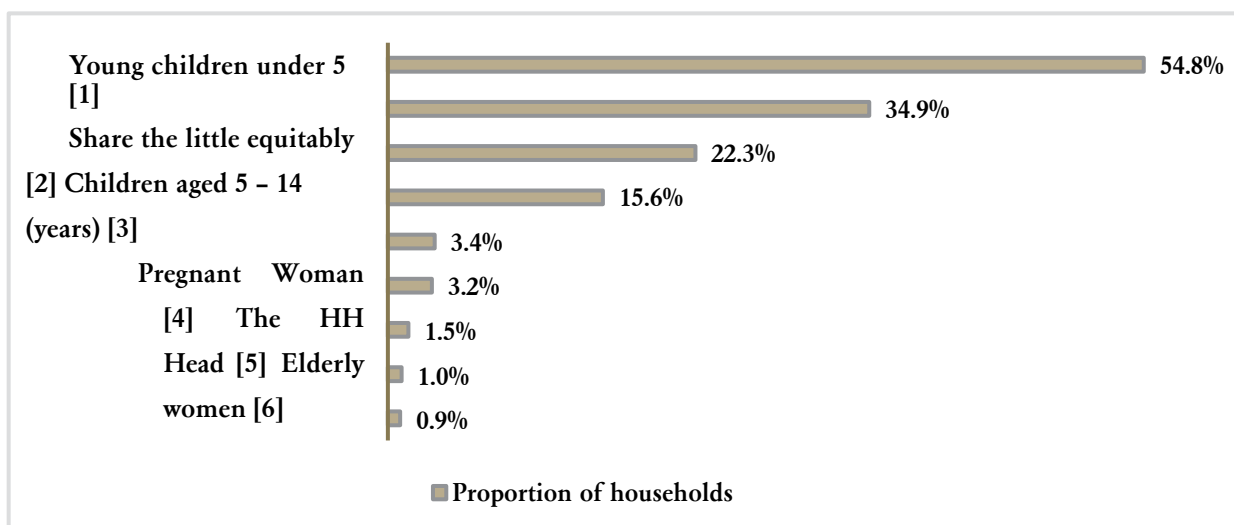


Figure 19: Priority HH members when there is food insecurity

### 3.6.6 Drivers of food insecurity

Household demographic composition plays an important role in determining household food security outcomes in this case, measured using Household Food Insecurity Access Scale (HFIAS). Results in Table 50 of a multivariate Zero Inflated Poisson regression model suggest that presence of a member with higher education in the household significantly decreases household food insecurity. Though the effect size is near zero, large households also have a lower likelihood of being food insecure. Additionally, increased access to credit increases likelihood of being food secure. This highlights the role of access to credit in household access to food in proper quantity and quality for good diet by through increased disposable income to facilitate purchase of diverse foods and in perhaps adequate amounts. Additionally, age in this case is shown to have a positive correlation with food security of bean farmers and negative with maize farmers. This suggests that a unit increase in age may increase chances of food insecurity of bean farmers whereas the food insecurity situation significantly decreases with age of a household head in the case of maize farmers.

Adoption of improved bean and maize technologies significantly decreases the likelihood of farming households being food insecure. We reason that a higher crop output may be the underlying driver here, implying that adopters increase their quantity of available food for household consumption through increased yields of improved varieties. Our results agree with a similar study in South-Central Uganda (Apanovich & Mazur, 2018), which showed that higher bean and maize yields were associated with food security. Also, access to non-farm income exhibited a negative correlation with food insecurity implying that the higher the non-farm income, the lower the likelihood of being food insecure. However, the role of non-farm income in food security was not significant implying that perhaps it was generally low and close for all farmers.

**Table 50: Predictors of household food insecurity access scale**

Variable (Y=HFI Indicator)	Poisson regression marginal effects Coeff. (dy/dx)		
	Pooled sample	Bean farmers	Maize farmers
Sex of household head (yes, 1/0)	0.0426 (0.174)	0.352 (0.247)	-0.221 (0.240)
Age of household head, years	-0.268 (0.244)	0.289 (0.370)	-0.863** (0.324)
Years of education, years	-0.088** (0.028)	-0.070 (0.042)	-0.116** (0.035)
Household size, number	-0.043** (0.021)	-0.058 (0.033)	-0.032 (0.026)
Access to credit, (yes, 1/0)	-0.288 (0.218)	-1.054 (0.326)	0.396 (0.292)
Technology adopter (yes, 1/0)	-1.092** (0.544)	-1.568 (0.591)	-0.229 (1.489)
Access to nonfarm income, 1/0	-0.176 (0.150)	-0.192 (0.203)	-0.074 (0.244)
Constant	-0.308 (0.531)	-1.344* (0.780)	0.369 (0.692)

Note: Values in parenthesis are standard errors; coefficients in green were significant with  $P < 0.05$ . HFI denotes household food insecurity (based on the HFIAS which runs from 0 – 27, with 0 meaning absence of food insecurity which increase towards 27)

### Summary

Results show that majority (61%) of the households obtained food through own production. Further, adopter households were more food secure (76%) compared to the non-adopters (63%) based on food consumption grade which underscores the contribution of improved technologies to food security.

The statistics from the study reveal that the weekly mean number of days for consumption of different food groups was higher among adopters relative to non-adopters. Similarly, more adopters with acceptable food consumption reported a higher mean weekly consumption of staples including maize of at least 6 days compared to non-adopters (Annex 14). In addition, a high mean weekly (5 days) consumption of pulses with beans listed among the first 3 crops was recorded among the adopters. The study further showed that households mainly consumed 3 meals per day during the harvesting period and two or less meals in lean seasons.

Findings of this study indicate that bean and maize farming households were highly dependent on the two crops for their food security. A large percentage of the bean and maize farmers consumed beans and maize on at least 3 days in a week and the contribution to dietary energy was about 53 percent and 43 percent of the required energy intake for the active women and men, respectively. Additionally, the study findings reveal that adoption of improved NARO bean and maize technologies increased household food security other factors notwithstanding. The increased food security is attributed to not only better food availability in stocks for household consumption, but also to better household income associated with bean and maize technology adoption.

### Recommendations on food security

The increased food security observed among bean and maize adopter households calls for continued promotion of NARO technologies, efforts to increase yields and diversification of food types in all zones. Further efforts should be directed towards availability of certified seed, strengthening research- extension-farmer interface, community-based farmer seed production, capacity building of the farmers along value chains for improved production, post-harvest handling and marketing.

Promotion of appropriate post-harvest handling technologies is recommended. Additionally, farmers should be encouraged and, in some instances, compelled through community by laws to store sufficient food stuffs that can serve as reserves during lean seasons and food price fluctuations. The farmers can be supported with modern storage technologies like silos to ensure safety and increased number of foodstuffs saved for a long period of time.

An early warning system should be developed and facilitated to ensure timely issuance and dissemination of early warning messages for cropping seasons. In addition, there should be prompt food security and nutrition surveillance for timely appropriate actions by associated authorities.

### 3.7 Contribution to gender empowerment

#### 3.7.1 Introduction

Despite the different interventions employed to empower women in the agricultural sector, very few women are accessing production resources and earn a decent life through agriculture. NARO has strived in mainstreaming gender in all her research interventions. Women often lack access to productive resources such as land, agro-inputs, labour, information, and skills that subsequently hinder their ability to invest in development interventions. Contribution of bean and maize technologies towards gender equality and empowerment has not been established.

This section makes an in-depth analysis of the gender dynamics in beans and maize production to determine the extent to which bean and maize technologies and interventions have fostered gender equity among households. Analysis was done at three (3) main levels namely: Outreach (participation and access to technologies by women and men); Benefits (benefits derived from adoption and utilization of production resources by women) and Outcomes (changes in agency-empowerment). Details are described in the subsequent sections.

#### 3.7.2 Outreach level

##### Participation in interventions

At the outreach level, respondents (FGDs, KIIs) indicated that access to production resources and participation in value chain activities by women and men was dependent on characteristics of household (i.e., female headed, and male headed), category of farmer (subsistence or commercial) and the nature of production within the household (sole or joint production). Within male-headed

households, gender roles in production, processing and marketing were observed to vary slightly. In relation to beans, women were more involved in land preparation, ridging, seed selection, planting, weeding, harvesting, drying, threshing, sorting, and storage compared to men. On the other hand, men engaged more in land preparation, fertilizer application, harvesting, transportation, storage, and marketing of maize.

It was further observed that women in both Female Headed Households (FHH) and Male Headed Households (MHH) mainly participated in bean production activities for food security and income generation as opposed to men who engaged more in maize related activities for income generation. Respondents in FGD (mixed women and men) indicated that despite the noticeable disparity, a few women and men participated in chain activities of both crops as either sole or joint production. Most women observed under joint production were

mainly under MHH, producing for income (commercial production) except for a few under sole production of beans and maize for food security purposes. Based on the understanding of the nature of participation described above, the extent to which women and men in both FHH and MHH were accessing and participating in technology interventions activities was determined



Inclusive participation of men and women in production

Figure 20 shows the proportion of FHH and MHH participation in technology intervention activities where MHH were higher among adopter farmers compared to the nonadopters. Majority of FHH reported that they entered joint production of the crops with their spouses for income generation (commercial production) unlike before when they solely produced the crops for food. Therefore, there was an increase in women participation in technology interventions. Women further reported that relevant institutions engaged and sensitized them on good agronomic practices and enterprise development.

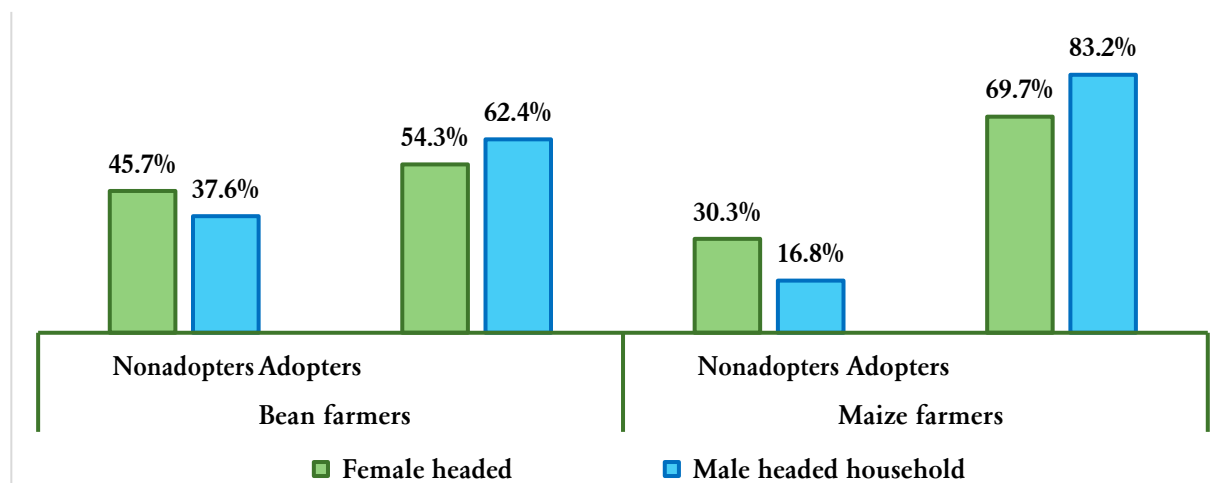


Figure 20: Proportions of FHH and MHH participating technology interventions.

Increased involvement of women in bean and maize production was due to their interests in increased food security and income. Women continued to be a major source of labour due to the culturally acceptable norm. Women's involvement in crop farming for income was minimal as several respondents highlighted the fact that women were still not permitted to cultivate crops for sale in their communities. This constrained women's access to land for production.

Because NARO was promoting technologies with the idea of income generation, MHH are getting more interested in the technologies to the extent that they are now equally interested in bean production for income generation.

#### Access to information and training

Figure 21 shows that overall, male-headed households (68%) had access to agricultural information compared to the female-headed households (60%). Female adopters (78%) for beans accessed more information compared to men (70%). These observations are collaborated by insights gathered from respondents in FGDs and KII. Women bean farmers in Lira cited a scenario where group representatives selected for training return and share information with group members stimulating further learning and information exchange. Majority of women farmers in FGDs also revealed that group engagements increased their access to information. Respondents also noted that the type of information also determined its access by FHH and MHH.

From FGDs, respondents reported that the existence of different information channels like radios, mobile phones, presence of NGOs and middlemen supported farmers to access diverse information about maize and bean technologies, agronomic practices, and skills. FGD's reported that extension services had slightly improved but more was still desired to enhance many farmers at village level.

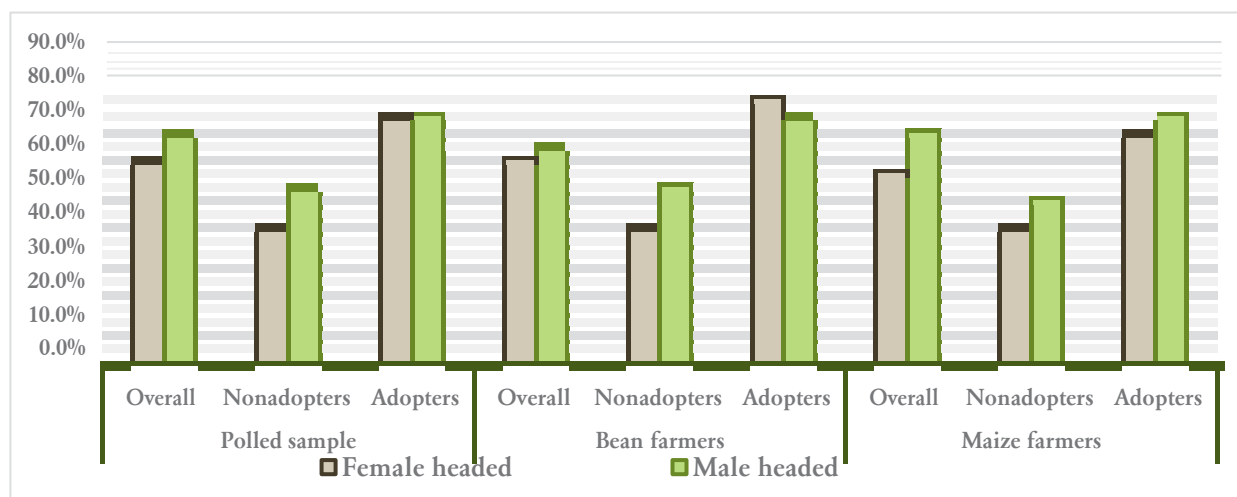


Figure 21: Access to information by gender of household head

### Types of information Accessed

Results show that there was more access to most types of information among adopters compared to nonadopters for both FHH and MHH (Table 51). Information on beans and maize agronomy was the most accessed (63%) by both FHH and MHH. Information on improved varieties stood at 51 percent and 44 percent for MHH and FHH, respectively. This was followed by postharvest handling information (26% for MHH and 20% for FHH adopters). Both types of households accessed seed information at 15 percent. This is corroborated with information from FGDs held with women bean farmers in Ngetta who indicated they engagement in bean seed multiplication for extra income.

Table 51: Types of information accessed by FHH and MHH households

Type of information	Percent of farmers			
	FHH		MHH	
	Nonadopter	Adopter	Nonadopter	Adopter
Improved varieties	19.2	44.3	27.0	51.4
Seed	13.3	15.5	12.3	15.0
Bean & maize agronomy	30.8	62.9	44.7	63.1
Postharvest handling	10.0	26.3	13.8	20.5
Agricultural marketing	2.5	5.2	4.7	6.9
Sustainable land use mgmt.	3.3	7.7	3.8	7.9
Climate adaptation measures	1.7	2.1	2.2	1.0
Weather information	2.5	1.5	1.9	1.7
Other agricultural information	1.7	0.0	1.3	0.6

## Sources of Information

The main sources of information were extension agents accessed by 64 percent among both FHH and MHH adopters, fellow farmers (36%, 41%), radio (37%, 47%) and research (11%, 13%) (Table 52). The results are comparable to the non-adopters. These results indicate improved access to information by women and men. Surprisingly despite significant resources used in farm clinics, trade shows/ fairs and television, they are negligible as sources of information. Additionally, mobile phone and Internet are not accessible sources of information.

**Table 52: Comparison of mode of information access by gender**

Information channel	Percent of farmers			
	Nonadopters		Adopters	
	FHH	MHH	FHH	MHH
Extension agents	70.6	55.9	63.6	64.4
Fellow farmers	52.0	39.3	36.8	41.3
Radio	34.3	40.7	37.1	47.4
<b>Researcher</b>	<b>15.7</b>	<b>14.3</b>	<b>11.2</b>	<b>12.9</b>
Farmer field schools	5.9	11.8	9.0	9.7
Newspaper	1.0	0.3	0.6	1.2
TV	0.0	0.3	2.8	6.6
Internet	0.0	0.8	0.0	0.4
Mobile phone SMS feature	0.0	0.8	3.1	2.2
Posters	0.0	1.4	0.0	0.4
Trade shows/fairs	0.0	0.8	1.6	4.5
Farm clinics	0.0	4.8	7.5	4.7
Other mechanism	2.0	2.8	5.9	3.5

Additionally, the percentage of men that had access to agricultural extension through training was higher by about 6 percent in relation to that for female headed households (Fig. 22). However, the percentage of adopters in male and female headed households who had agricultural training was statistically not different.

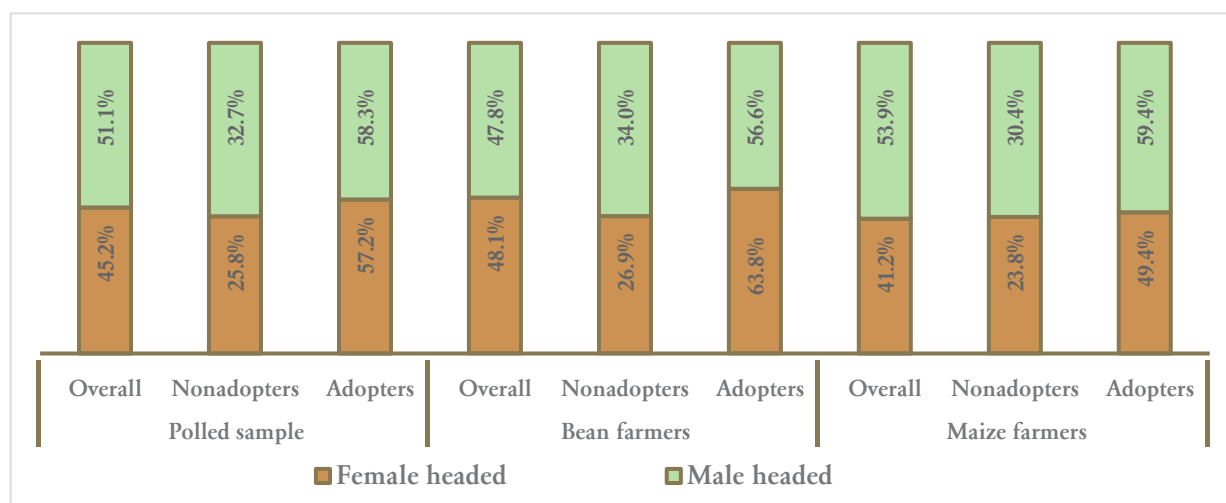


Figure 22: Access to extension training by household gender

### 3.7.3 Access to production resources

#### Access to improved seed

Own saved seed and seed from fellow farmer were the major sources of seed for both adopters and non-adopters (Table 53). There was higher access to own saved seed (70%), and fellow farmers (25%) seed sources in non-adoption areas compared to adoption areas by both MHH and FHH. Among the adopters, MHH (36%) and FHH (28%) accessed local grain markets more for improved bean and maize seed (Table 53). Access to seed by MHH (11%) from farmer groups was higher compared to FHH at 5%. FHH (14%) had more access to seed from gov't program sources in adoption areas compared to 12% of MHH. However, the high level of use of own saved seed and fellow farmer (70%, 25%) among female nonadopters, which is not improved, is a constraint to improved production to women.

Table 53: Sources of seed

Source of seed	Percent of households			
	Female headed household		Male headed household	
	Nonadopters	Adopters	Nonadopters	Adopters
Fellow farmer	25.2	22.2	38.4	23.7
Own saved seed	70.0	32.5	61.7	27.7
GOVT/NAADS/ OWC	2.0	14.2	1.9	12.2
NARO	0.3	4.9	0.5	5.6
NGO	0.3	7.2	1.2	5.8
Farmer group (FG)	1.3	4.8	0.4	11.2
Local grain market/shop	13.1	28.6	12.9	35.6

Despite the above results, women and men (mixed FGDs) reported that access to improved seed had generally increased; most women farmers (FGDs/women) indicated that access varied. For instance, many women bean seed growers in Lira indicated accessing improved seed from NARO. In Mubende, women farmers had taken to commercial production of bean seed supported by NAADS. Despite different arrangements by women and men farmers to access seed, respondents reported that the amounts availed through government sources was still very little hence most of them still relied on informal sources to access improved varieties. Variations in access were also dependent on the characteristics of household and type of production. Different KIs (Ngetta and Abi DLGs) revealed that despite interventions to increase participation and access, to seed, majority of women in MHH and FHH still faced challenges to access improved seed. In this regard, one lady had this to say:

*...We hear improved bean and maize seeds are brought and distributed at the chairperson's home sometimes, but people are just chosen. May be if you have money, you can get but for me without anything where do I get the money to buy that seed. Chairman cannot give me seed for free, as who?"*  
(Adopt FGD/WG) Mubende 26th/02/2021)

#### Access to credit by gender

Overall access to credit was comparable, 64% between FHH and MHH (Figure 23). Among adopters' access to credit was higher in FHH (69%) compared MHH (65%). A similar trend was observed with accessing credit for the two crops, with the highest number of FHH (70%) accessing credit to produce beans in adoption areas (Fig. 23).

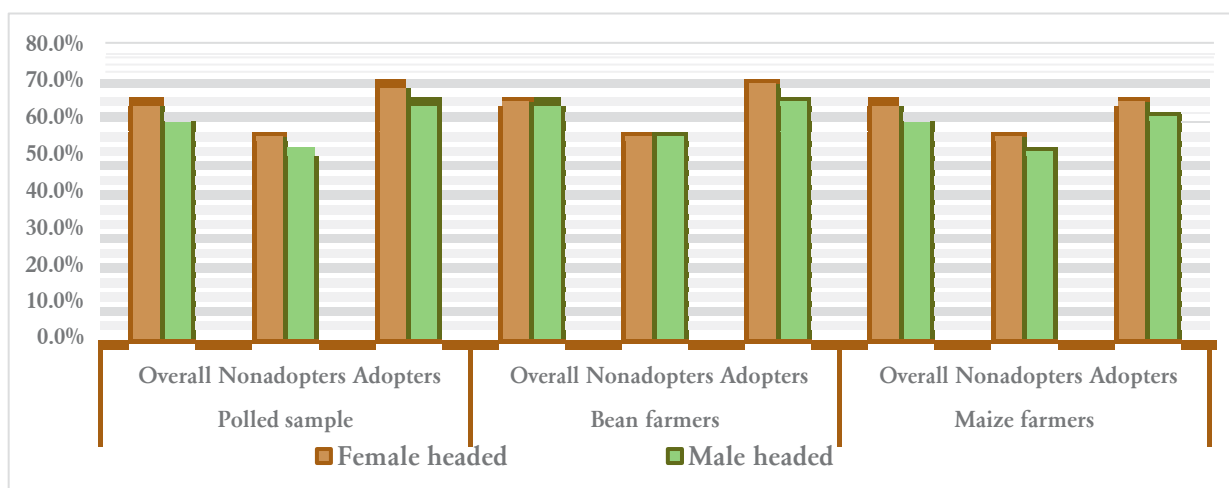


Figure 23: Access to credit by gender

#### Sources of Credit

Informal saving schemes (37%) and SACCOs (19%) were the major sources of credit (Table 54). FHH adopters accessed credit through informal savings schemes and SACCOs (42%, 22%) compared to MHH (38%, 20%). Access to credit through formal institutions was low. Relatedly most key

informants argued that despite the increased access to credit for women, access from formal credit institutions was still low compared to their male counterparts. Furthermore, majority of women under the study indicated challenges in accessing credit especially from NGOs, MFI, government credit schemes and banks due high interest rates and collateral requirements. In this regard, a lady from the group commented that:

*'The amount of beans I harvest is even not enough to feed my family, now I get a loan, where will I get the money to pay back when the beans don't grow or when we eat all? Nobody can even stand as my surety because they all know I cannot afford'... (Adopt FGD, WG/Mubende 26/02/2021).*

**Table 54: Sources of credit by gender**

Sources of Credit	Percent of households				
	Female headed household			Male headed household	
	Overall	Nonadopter	Adopter	Nonadopter	Adopter
Informal savings scheme	36.8	37.5	42.8	29.6	38.1
SACCO	19.3	15.8	22.7	17.3	19.8
Bank or DFI	7.0	1.7	5.7	7.2	8.0
Relative/ friend	2.9	0.5	2.1	03.1	2.7
MFI	2.0	2.5	0.5	1.9	2.3
Money lender	1.4	1.7	0.5	1.3	1.6
NGO	0.8	1.7	1.5	0.6	0.6
Gov't credit scheme	0.6	0.8	0.5	0	0.9
Employer	0.2	0	0	0	0.4
FBO	0.2	0.0	0.5	0.0	0.2
Other sources	3.0	1.7	4.1	3.8	2.6

Majority of women farmers indicated that VSLAs encouraged them as farmers to save, borrow and pay back with low interest rates. SACCOs on the other hand encouraged savings and credit access for larger groups.

In addition, respondents reported that when approached, they got less money than the amount often requested for and besides, are often out of their reach, one had to incur costs to get there.

*"Credit facilities limit funds for agricultural financing in addition to setting unfriendly terms for credit access. Farmers including women are relying more on informal credit sources that provide limited funds to enable increased investments. Formal credit facilities are in better position to provide higher credit packages but should be structured to offer more friendly loan terms to enhance smallholder farmers, especially women, access to credit to enable them to invest and expand their enterprise. More focus should be put in enhancing the ability of informal lending schemes and SACCOs to grow and provide more credit to farmers. This approach could go a long way to supporting FHH to invest further in beans and maize production". (FGD, mixed AbiZARDI).*

## Land for production

Focus group discussions revealed that majority of the women did not own land. They reiterated that most of the land they use for growing crops was owned by their spouses under customary tenure. Nonetheless, they indicated that since it was their role to produce food, some portion was normally allocated to them, in agreement with spouses, to produce beans and maize for consumption. If women wanted to expand production beyond food, they said it was upon them to hire or buy if they had an income. Although respondents mentioned that access to land had increased for bean and maize commercial production, they indicated that it was mainly for most women (CP) in FHH and MHH engaging in joint production (JCP1) with their spouses. While they had the liberty to freely utilize land for food production, most of the women in the subsistence production category especially in Kabale, noted that most of the plots allocated to them for that purpose were small, infertile, with limited ability to allow crops yield highly despite using improved seed. However, in Lira, women bean seed growers (CP) indicated that with the increased demand for improved bean seed in the market, most of them had resorted to hiring and buying land. These findings corroborate with studies and frameworks, which indicate that customary systems restrict or prohibit land ownership by women placing them in a fragile state asserting their limited control and inability to derive full benefits from it (Acosta, et al, 2015; Sustainable Land Management Policy, 2013; Land Act, 1998).

### 3.7.4 Benefits Derived from Adoption

#### Crop yields and land areas

The promotion of improved bean varieties especially (NABE 1 NAROBAN 2, NABE 19, NAROBAN 3) preferred by women for their high yields, early maturity, disease, and pest tolerance, colour and taste not only contributed to increased crop yields, but also household incomes. Despite maize being a man's crop, majority of women farmers in both FHH and MHH on the other hand, reported increased adoption maize varieties such as LONGE 5, LONGE 10H, and PANNAR for their good attributes (ref adoption section). Their interest in improved maize varieties was to not only meet household food security demands but also their household incomes. Disaggregated crop yield data showed significantly bigger areas in hectares (0.5 and 0.6 maize/0.7 and 1.1 bean) allocated for maize and bean production respectively compared to non-adopters (0.3 and 0.1 maize/0.5 and 0.7 beans) implying an increase in land area for production of both commodities with more land being allocated to bean production. Results also show significantly higher yields in adoption areas under FHH and MHH except for bean yields in FHH among adopters.

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<sup>1</sup> JCP: this refers to joint production of beans and maize by both spouses in a male-headed household. This was common in commercial production

Despite increased yields among adopters, majority of female respondents in both FHH and MHH with limited opportunities for accessing seed and complementary technologies reported that increments in crop yield especially beans were not noticeable. Studies have further shown that despite promotion of improved seed technologies women yields may not necessarily increase due to differences in access and use of inputs such as improved seed, fertilizer, labour, credit, information, and low levels of education (Mukasa and Salami 2015). Ultimately, there is need for NARO and government to put more focus on challenges affecting resource among women and men and in both FHH and MHH to increase their production.

## Food security

### Food consumption grade

Further observation of quality of food eaten by male and female-headed households (Fig. 24), it emerged that the percentage of female-headed households (71%) consumed food of acceptable grade over a period of a week prior to the survey was comparable to that of male-headed households. Similarly, food of poor quality consumed between MHH and FHH were comparable (10%) for both commodities. Rural households tend to grow similar crops and therefore mirror the quality of food consumed.

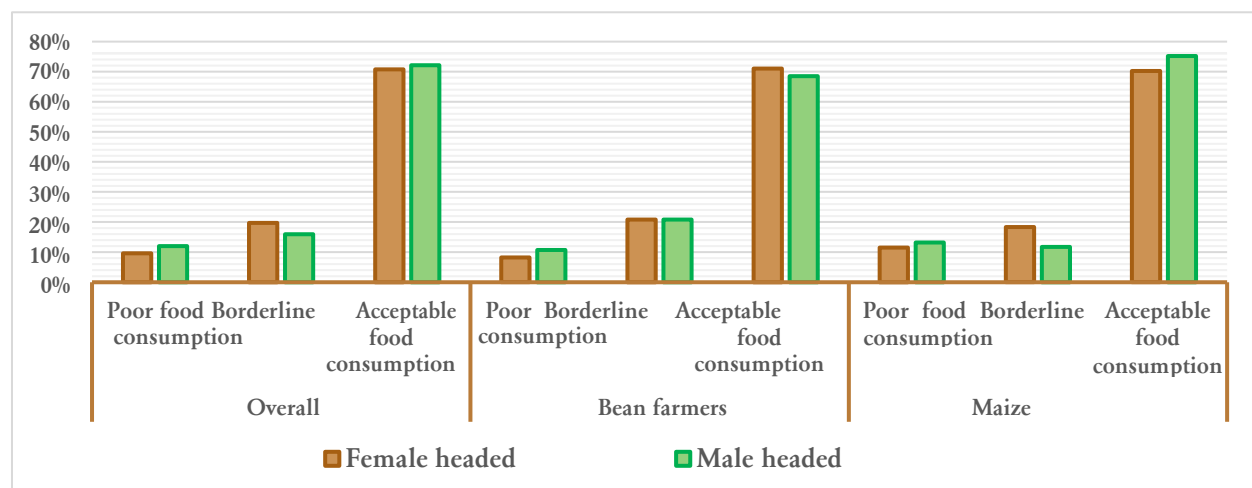


Figure 24: Food consumption quality by gender of household head

### Prevalence of food insecurity

Figure 25 shows that the prevalence of food insecurity among male and female headed households was not different standing at about 28 percent while food security was about 65 percent among the male headed households compared to 61 percent in female headed households.

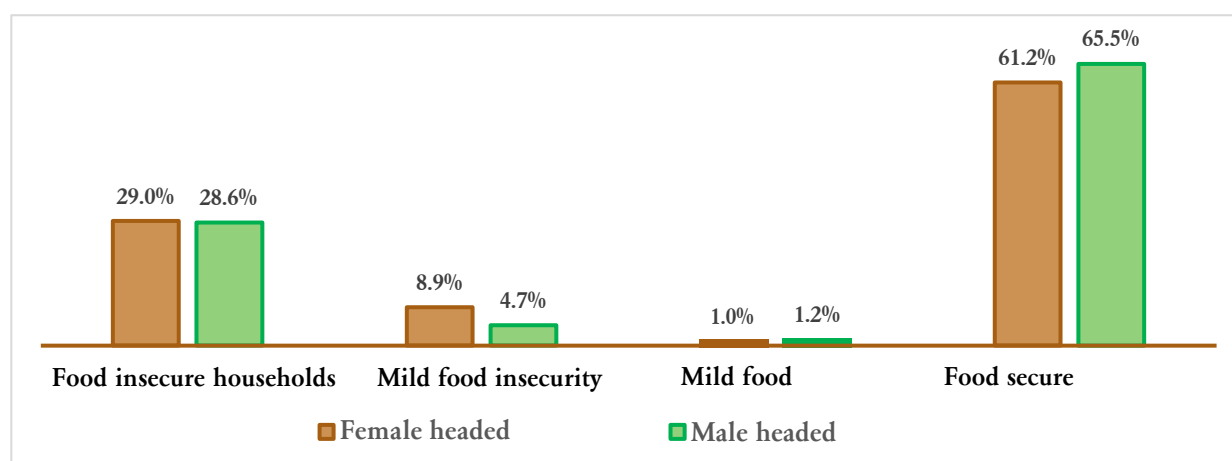


Figure 25: Food insecurity among female and male headed households

As elaborated by majority of women in both FHH and MHH, farmers in the communities depended on beans and maize for both food and income generation. Although the amount of beans and maize sold differed, most women (both CP, SP) indicated that they sold some portion of their harvest to purchase other foodstuffs. In addition, the presence of enough food (described by a household having at least 2 and 4 sacks of maize and beans in the house off season), had limited the emergence of conflicts between spouses given that availability of food and absence of prolonged hunger kept household members happy. In this regard, a lady (SP) in one of the focus groups in Iganga had this to say.

*“These crops have helped to make our lives better, when I eat those new beans I have no blood deficiency, and also my kids who were malnourished now look better, what would have made us quarrel in home that kids have no blood, beans would save me”. (Adopt FGD, MG, Women, Iganga. Sept 21, 2021)*

With the income accrued from selling beans and maize, majority of female respondents reported purchasing different foods such as fruits, vegetables, fish, meat, rice, chicken, bread among others to supplement their diet and nutritional needs. In addition, they didn't have to worry about buying maize and beans for food because these were available in store after harvest. In this regard, this is what one woman said.

*“We even rent land these days and grow even more beans and maize those working together even get more yields of course.*

*That's why they can buy other food especially meat, chicken, vegetables, milk, fish. Even when you have harvested these crops and they are stored in the house when you want, one just goes and scoops rather than buying”. (Adopt, FGD, WG, Lira, CP, Sept 20, 2021)*

### 3.7.5 Gender empowerment

#### Household income

Table 55 compares incomes between the female and male-headed households both from farming and non-farming activities. Results show that total income of FHH (UGX.3,660,235) was significantly lower than that of MHH (UGX.6,168,830). This is equivalent to 41% lower. Likewise farm income of FHH (UGX.2, 421,970) was significantly lower than the MHH (UGX4, 169342). Incomes from beans and maize were UGX. 980788 for FHH compared to UGX, 1351305 for MHH. These results indicate that incomes of FHH are persistently lower than those of MHH indicating gender inequality. This is partly explained by limited access to production resources and access to marketing by women.

**Table 55: Income of female and male-headed households**

Income source (2020)	Mean household income (UGX)								
	Female headed households				Male headed households				P stat
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Beans/Maize	980788	2262856	0	25,200,000	1351305	2297627	0	31,500,000	0.0113
Other crops	794024	1283612	0	7,850,000	1570472	2413655	0	28,300,000	0.0000
Livestock	392841	866515	0	7,500,000	739374	2087067	0	30,000,000	0.0041
Livestock pdts	254318	2083090	0	36,000,000	508191	3944200	0	92,200,000	0.2721
Farm income	2421970	3837951	0	41,300,000	4169342	6164164	0	97,700,000	0.0000
Nonfarm	1238265	3250235	0	30,000,000	1999488	4536690	0	63,600,000	0.0055
<b>Tot. HH income</b>	<b>3660235</b>	<b>5402627</b>	<b>0</b>	<b>43,900,000</b>	<b>6168830</b>	<b>8493864</b>	<b>0</b>	<b>103,000,000</b>	<b>0.0000</b>

Note: SD denotes standard deviation

#### Income change

Results in Table 56, indicate that incomes from beans and maize were significantly higher in 2020 (FHH-981, 000) and (MHH 1,350,000) compared to 2016 (FHH-280, 000) and (MHH-634, 000). The

same trend was observed with total HH income in 2020 (FHH-3, 660,000), (MHH-6, 170,000) compared to 2016 (FHH-1, 630,000), (MHH-2, 690,000). Despite the increase, many female respondents said their yields depended on production inputs labour, income, and agro-inputs. The perception of both women and male farmers in most FGDs was that beans and maize yields had increased. They added that the increased yields have contributed to an increase in household income. This is evident in the results explained where, generally, total HH income with the introduction of beans and maize significantly increased in adoption areas in both FHH and MHH (refer- table on income in adoption section).

Table 56: Change in income of beans and maize

farmers. Income	Mean household income (UGX)					
	Female headed households			Male headed households		
	Mean (2020)	Mean (2016)	P stat.	Mean (2020)	Mean (2016)	P stat.
Beans/Maize	981000	280000	0.0000	1350000	634000	0.0000
Other crops	794000	-		1570000	-	-
Livestock income	393000	370000	0.8270	739000	492000	0.0001
Livestock products	254000	145000	0.3276	508000	148000	0.0014
Farm income	2420000	795000	0.0000	4170000	1270000	0.0000
Nonfarm	1240000	830000	0.0173	2000000	1420000	0.0000
Tot. HH income	3,660,000	1630000	0.0000	6,170,000	2690000	0.0000

### Access and control over production resources

#### a) Income from sales of crops

Despite the increase in income over the last 5 years (2016-2020), responses regarding access and control over incomes for both men and women in FHH and MHH differed according to category of farmer (SP/CP), type of household and agro ecological zone. In KAZARDI, men had overall control of incomes from sales of beans. In BUGIZARDI, while men marketed the produce, they would bring back the money for budgeting with spouses. In addition, women in BUGIZARDI had some control from the proceeds of sale of beans and would use the money as preferred including acquisition of assets. These scenarios were explained verbatim as below.

*“Men of this days are different from the men of the past. They do not poke their noses everywhere. So we can do our own things. We even represent our men on occasions such as participation in clan meetings. We represent them and even make financial contributions in such meetings; we claim it is the husband's contribution, yet it is me the woman who has got the money”* (FGD, MG, Iganga, district 24<sup>th</sup> September 2021)

*“When money comes from sales, most agree [men] we plough back some of the money, if you have kids who go to school, you then get off the fees, then the balance is given to me as a wife because I am charged with buying the essentials of the households”* (Mutufu FG, Sironko district, 22<sup>nd</sup> September 2021)

*“While we do most of the farm activities, man comes at selling. He markets the produce. Much as he brings back the money, several cases, he makes a difference (enjawulo) by reporting less weight and price sold on to the wife. Money is put on the table for budgeting by both women and man. But still the man keeps putting in extra money/ prices to make enjawulo.”*

*(Women's Group, Kagyera Village, Rubaya, Kabale District, 2<sup>nd</sup> September 2021)*

Many women (CP) in MHH engaged in joint production with their counterparts revealed that their control over income from the two commodities over the last 6 years had increased. However, majority of women (SP) in MHH had a different view. They indicated that their access and control over income had barely changed despite the increase in HH income. Their spouses still controlled most of the proceeds. The difference as mentioned was engagement in the allocation of money for household requirements. However, they said that they controlled income gained from selling small portions of

beans/maize at farm gate used to buy other foods/fruits and household requirements like march boxes, salt, and sugar. The perception of woman (CP) in FHH and MHH with slightly higher education above average differed slightly with the other women (CP/MHH) that were less educated. In this regard, a lady remarked: -

*... "Some of us who are in business have increased our beans and maize production by renting more land from different places. When you rent land or buy land it's you in control of the money that comes out of it, even if you are jointly farming you can still have control because your part of the business. So, for me I think control of money by women selling produce has increased these days because of our efforts in getting more land."* (Mutufu FG, Sironko district, 22<sup>nd</sup> September 2021)

#### b) Credit/finance:

Despite the increase in credit access by women, respondents in FGDs observed that 6 years ago women didn't belong to groups and access to credit was a challenge. To date many of them have joined different groups including saving schemes where they can access credit with less demands as opposed to formal institutions (banks and micro finance) that demanded for collateral with high interest rates. Many female respondents indicated that given the conditions set by formal institutions most of them relied on their spouses for their credit needs (collateral) and hence had limited control over the credit accessed. However, currently they can access and control credit from saving groups. In addition, engagement in joint commodity production has enabled them to jointly access credit given that they are able to pool resources or use their land as collateral to access credit services. As remarked by a woman member:

*"Most money we use in agriculture is from borrowing we save as groups and we also go to the banks. You must have an account. We also use our houses/ land as collateral. Husband or wife must sign. We also need a guarantor."* (Mutufu FG, Sironko district, 22<sup>nd</sup> September 2021)

Respondents attributed their increased control and access to credit to joint engagement and cooperation in production, emergence of formal savings groups, increased information on credit access and increased abilities to plan and make decisions in joint production.

#### c) Decisions on production and productive resources

With regards to respondent's perception on decision-making, majority of women growing beans and maize indicated that their ability to make household decisions as well as production decision within the household had improved. Many women in FHH and MHH said that decision-making depended on the type of production (CP/SP), characteristics of household (FHH/MHH) and nature of household engagement (sole /joint). However, despite the increase in decision-making, majority of women (SP) MHH reported that decision was still dominated by men. Their level of involvement however depended on group membership, level of income and the level of financial support to the business. Even those in joint production (CP, MHH) observed that, they still did not use household income freely without seeking the consent of their spouses. However, FHH (CP) growing beans and maize confirmed that their ability to make decisions was not constrained since they were in control of the production. The overall increase in making decisions as reported by respondents was skewed

towards increased involvement in joint decision-making in MHH and increased ability (skills to plan better without the interference of men. In this regard, although the abilities of women (SP) in MHH had increased, their abilities to make decisions regarding production resources (i.e., land to cultivate, agro-input to use, labour access among others) had not increased to the extent of that acquired by women CP, bean/maize) in male headed households.

*“These days man and woman sit together for decision making. We discuss as man and woman. Gender awareness workshops have enlightened men to help women. The man no longer leaves the woman to carry both boes. The posts of vice and treasurer are for women. Women are trusted with fund keeping. We are trained in credit and expenditure. Women are equally trained.”* (Namungalwe FG, Iganga District, 24th September 2021)

*“We do not make decisions as women; we first consult our husbands to make decisions.”* Muyove FG, Busanza, Kisoro District, 4<sup>th</sup> September 2021

#### d) Workload

Perceptions gathered from respondents specifically those in MHH growing beans indicated that promotion of improved maize and beans varieties reduced women’s workload to an extent. They cited NAROBAN1, 3 KI32, NABE16, NABE17 and LONGE4 & 5 and LONGE7H maize varieties with special attributes such as early maturity noting that the varieties spent a shorter time in the field (3 months) hence reduction in the amount of weeding frequency in a season which means a reduction in workload. Row planting of beans was said to ease weeding hence less laborious.

*“New bean varieties have reduced workload for women, in the past with the old varieties, it was us women who would do all the field work and other activities related to beans. We would plant, weed, harvest and so on. But now we work with our husbands implying workload has reduced. In the past we used to randomly plant, but now we plant in lines and the man is ready to help in such a field.”* (Namungalwe FG, Iganga District, 24th September 2021)

*“Even men are harvesting and threshing beans including children. Women mainly winnow, since men cannot winnow.”* (Bala FG, Apongimala, Local Seed Business Group, Kole District, 20<sup>th</sup> October 2021)

Most women bean growers in Lira (CP, mixed group FGD) also went ahead to say that in the current joint production strategy their husbands have joined them thus a reduction in the time spent in the field. They also said the use of herbicides and pesticides in the field had enabled them to reduce on the workload incurred in land preparation, weeding, and collecting water for mixing pesticides. In addition, women groups (CP) that had taken on maize production mentioned that the new varieties were easier to remove from the cobs thus reducing on the post-harvest time and labour. However, although climbing beans had good yields and helped most women in Kabale with land fragmentation issues, women in this area said that the beans to an extent increased their workload citing collecting stakes and staking as a tedious management strategy in bean production. Nonetheless, based on these insights, majority of women in the adoption areas confirmed reduced workload with the introduction of beans and maize.

### e) Domestic violence

Information from selected FGDs and key informants (DAO Lira, Chairman farmer group Abi, village councillors Mukono) revealed that in the past (6 years ago) domestic violence was high mainly because majority of women in MHH were dominated by their spouses and they had limited control of production resources, decision making, time and mobility. Prior, majority of women in MHH households would conflict with their spouses, over produce, proceeds from sale of crops, credit, and control over resources, decision-making and limited mobility. Men's interest in produce during time of harvest was a big issue promoting conflict and violent behaviour. This meant that the spouse determined most of their actions including roles. They indicated that due to the many trainings and sensitization campaigns by institutions on the significance of co-operation in decision-making in most MHH, men have appreciated the outcomes. Engagement of women has led to increased yields hence income from crop production. In unison, they revealed that conflicts and flights that should have emanated out of men's desire to control and manage the proceeds from production were dwindling due to their joint enjoyment, cooperation, and ability to involve their spouses in decision making. In this regard a female respondent backed up by her fellow women in a focus group discussion had this to say:

*"What causes conflict is lack of money, When the man wants money, he can steal from your savings or even steal the beans or maize stored in the house when it's not his, these conflicts are mostly there during harvesting time in households whose members are in sole production and the women mainly runs the enterprise. The man waits for the women to harvest and then takes the produce by force, steals, and goes to sell. Sometimes when the women refuse, he turns aggressive. Those days it was worse than these days. As said most households are now working together. A few who are not yet in joint production are the ones exhibiting those scenarios"* (FGD, Mixed, CP woman, Lira)

*"Money is a major source of GBV. A poor man is a wounded lion. But it is also influenced by women's behaviour. The man is our head. We should not challenge him. We avoid GBV by you as a woman to have your crops and gardens where you plant crops for household food security and your income."* - (Namungalwe FG, Iganga District, 24th September 2021)

*"GBV potential areas, arise a when the harvest is snatched (by either man or woman), money from beans sometimes you let her keep the money from beans and then she spends it without your knowledge."* (Muyove FG, Busanza, Kisoro District, 4<sup>th</sup> September 2021)

This argument was supported by majority of women in MHH in other study areas who went on to say that with the introduction of the new varieties, yields had increased. Insights from majority of respondents further revealed that the declining rate of domestic violence within MHH households was a result of sensitization and awareness programmes on issues regarding gender and domestic violence especially by civil society organizations within the area. An example, was the women (bean seed growers) in Lira who indicated that they were trained by World Vision on agri-business and household co-operation) These changes as described, were due to sharing ideas, co-operating, listening to the teachings being offered and responding to family agribusiness matters positively.

#### f) Improved food security and household welfare

Majority of respondents indicated that they produced and stored beans and maize for food security purposes. Most women (SP) in FHH and MHH indicated that the main reason for growing the two crops was to address food security either from direct consumption of the products or proceeds accrued from the sale of the two crops. The situation was also reported to have changed from six years ago when bean and maize production was too low to the extent that majority of families in FHH and MHH were food insecure. To date, however, these households can sell beans and maize to purchase other required items such as foodstuffs and cater for their health. This confirms that food security and household welfare among adopters increased with the introduction of beans and maize technologies. This is reflected in the views of FGDs indicated:

*“To-date we can say we have food to eat, and we eat even many times (3) a day compared to 5 years ago. Those days the varieties we used to grow were low yielding, the amount of beans and maize that we used to harvest was so low that we barely saved some for food. We even have more beans and maize available for eating so we don't go hungry unlike those earlier times.”* (Adopter, FGD, Mixed AbiZARDI)

*There is improvement in food security compared to five years ago, before starting Local Seed Business. When I was growing up, we used to have frequent famine. But now production is planned in a way that old harvest meets the new one. Maize is mainly for cash. We sale most of it and leave two bags for food security. Also, a sizeable quantity is left for food. My motorcycle was stolen, but when I sold my Quality Declared Seed. I had to buy new one, using money from beans. One time I was sick, and there was no money for treatment. I took the maize to the store and used the money to treat myself.”* - (Bala FG, Apongimala, Local Seed Business Group, Kole District, 20<sup>th</sup> October 2021)

*“When we sale our beans and maize, we make a budget, we buy Nile perch and eat well on that day, we look at priorities in the family: children's school fees, beddings for children. Also, as a woman, I visit my parents. We buy livestock and home equipment from the money got from beans and maize. We also buy some land if money allows. We discuss it as man and women. I am a woman, I bought land from earnings from maize. We used our money from maize to build this garage.”* (Namungalwe FG, Iganga District, 24<sup>th</sup> September 2021)

*“(Mukyala nga anyirira, emmere weeri) ..... when a wife looks good then there is food. People are selling food everywhere, people are cooking food, you see smoke at every homestead especially between August and February when there is plenty of maize and beans.”* - (Mutufu FG, Sironko district, 22<sup>nd</sup> September 2021)

The increase in food security and household welfare was attributed to increased yields, incomes, information, and skills acquired by majority of respondents participating in beans and maize production.

#### g) Group membership

Perceptions from both male and female respondents in the study areas indicated that many of them joined groups and the number of groups that were established increased. The groups cited included savings, beans and maize production, burial, catering, agro-inputs dealers, and marketing that were established over the past 5yrs. They indicated these groups enabled them to actively participate in- group activities hence bond, build trust and develop self-confidence. FGDs and key informant

interviews revealed that joining groups enabled members to easily access credit, gained skills, and information related to agricultural production. These groups also enabled them to collectively bargain for better prices for their produce. Participants in FGDs had this to say:

*“Benefits of being a member are very many. I access new seed varieties, I save money in the group which we share at end of year, I borrow money from the groups, we bulk produce (beans), and get one voice during negotiations and sale.”* (Member, Kayove FGD, Kisoro; KaZARDI).

*“The money saved and accumulate, we borrow to each other for economic investment, social problems, we also get profit. There are specific groups for beans and maize. I belong to NABE15 farmer group”* (Member, Mutufu FDG, Sironko; BugiZARDI)

From the perspective above, Group memberships increased which encouraged women in both FHH and MHH to join groups and to participate and reap from individual and group benefits arising from collective action.

#### h) Leadership

Leadership considers social influence to achieve a desired goal. Leadership can be both formal and informal. Results of the study of leadership indicated an increased role of women in formal leadership in groups. The leadership of women especially was profound in groups of savings and credit, seed store and marketing. Many groups required that the woman and her spouse became members to support issues of gender equality. There was a high trust for women in savings and credit groups as women were seen to be transparent, sincere, and trustworthy. These were some of the elements required to keep people's money well. In an FDG of Bara, AbiZARDI, a member remarked on how leadership composition changed over the past 10 years

*“During the last 10 years, we also learnt that women are better leaders than us men that is why we have 5 women leaders and men are 4. Most groups I know have women in the position of vice chairperson because you see, we came to realise that women give good advice. They easily point out problems in the group and give solutions. Money is very important when you are doing business and that is why only women are in finance committee to manage our money and the treasurer and vice are both women.”*

*“In our village SACCO, chairman is a man, a woman is treasure, woman is secretary for mobilisation, and women know how to keep money. There are more women than men in the SACCO, total number is 30 and women are 20. We are all trained in leadership at sub-county, in areas of how to control funds.”* (Apokor, Mixed Farmer Group, Mella subcounty Tororo District, 26<sup>th</sup> September 2021)

Respondents' perceptions on the status of these indicators in 2015 and 2020 were sought and compared to establish whether the lives of women and men at the household and community levels had changed with the introduction of improved bean and maize technologies.

Although the utilization of improved bean and maize technologies has contributed to gender equity, as explained above, there were some incidences when women were resisted from making choices and voicing their concerns. In such situations empowerment was inhibited. For example, women's empowerment in areas of resource allocation in factors of production is still low. Therefore, policies

towards women empowerment should continue to be enacted to promote group participation, choices, and voice equality.

### 3.8 Impact of technology adoption on household welfare

#### 3.8.1 Introduction

This study measured impact of NARO (improved) technology adoption on six outcome variables namely bean/maize output, productivity/yield, bean/maize income, total farm income, total household income and household food security. Total farm income comprised income from beans and/or maize, and other crops, livestock products and sales of live animals. Thus, total household income comprised total farm income and nonfarm income (salaries, business, informal labour employment, among others) earned by household members. Household food security was measured using the food consumption score for a seven-day short run recall and household food insecurity access scale scores for a 30-day period. To estimate impact, a comparison was done for the adopter farmers hitherto referred to as the treated group and non-adopters as the untreated group (control) using propensity score matching.

#### 3.8.2 Validity of impact estimates

##### Propensity Score Matching

A visual inspection of the distributions of estimated propensity scores (Figure 26) and the treatment assignment tables indicated that there was considerable overlap in common support meaning that the conditions of common support were satisfied. This implies that there are adequate observations in the treatment and comparison groups with similar or comparable propensity scores.

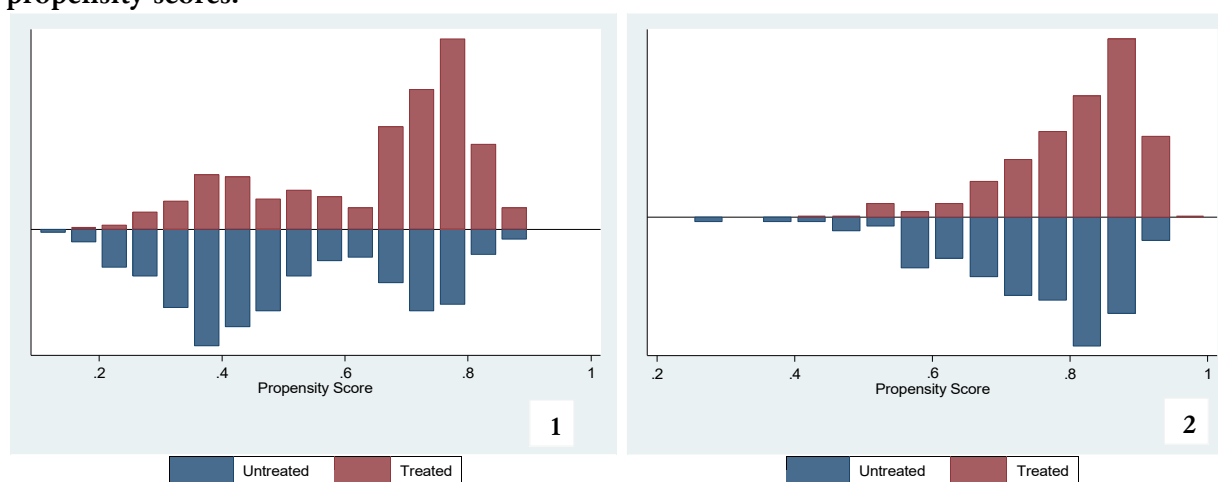


Figure 26: Graphs showing common support using nearest neighbour matching method for beans (1) and maize (2) farmers

## Balancing test

Table 57 presents results of the balancing test for each covariate after matching. A standardized bias and t-test were used to check if the matching procedure was able to balance the distribution of the relevant variables in both the control and treatment group. The t-tests indicate that the covariates

were not statistically different after matching (Table 57). Similarly, the standardized bias of all covariates was less than 20 percent. The low mean standardized bias after matching and the insignificant t-tests indicated that both groups have the same distribution in covariates after matching. Therefore, the results show that the matching procedure balanced the covariates in the treated and control groups. All results that follow are based on specifications that passed the balancing tests and the common support condition.

**Table 57: P test results for Kernel and Radius matching**

Variable	Standardized bias after matching			
	Maize		Beans	
	Radius matching	NN matching	Radius matching	NN matching
Sex of household	19.9	5.2	3.6	-1.8
Age of household head	6.4	-	-3.3	8.8
Household head marital status	-19.1	-6.6	9.8	-
Household head education, years	8.7	19.0	8.4	-4.4
Main occupation of household head	4.4	1.4	13.1	-
Group membership	6.5	-	7.4	0.4
Household size	9.0	17.5	11.8	12.9
Members contributing	20	-	8.8	9.1
Access to credit	20.9	-5.1	24.3	-0.2
Who makes decisions	-21.1	-13.9	-5.4	-
Farming experience (years)	8.6	3.8	-18.1	8.0
Narozone1	-	2.5	-	4.8
Narozone2	-	0.5	-	2.4
Narozone3	-	18.3	-	5.2
Narozone4	-	0.8	-	-2.2
Narozone5	-	-3.7	-	-3.5
Narozone6	-	-	-	-4.4

Note: NN denotes nearest neighbour matching method

## Rosenbaum sensitivity analysis

The Rosenbaum bounds sensitivity analysis was used to assess if our estimates based on matching are robust to the possible presence of hidden bias (Rosenbaum, 2002). This test shows that the effect of unobservable factors should have to reverse the findings based on matching on observables. Table 57 presents results of the Rosenbaum bounds sensitivity analysis for the ATT estimates. Overall, the critical values of  $\Gamma$  ranged from 1.2 to 1.9 and did not vary significantly between matching estimators and outcome measures. These are relatively low critical values, implying that these estimates are more

sensitive to hidden bias. This does not mean that hidden bias exists and that there is no effect of treatment on the outcome variable. This simply means that some of our estimates based on these matching estimators are not robust to the possible presence of hidden bias. Therefore, we cannot state whether the conditional independence assumption holds. Propensity Score Matching (PSM) is a useful approach for impact evaluation only when observed characteristics are believed to affect technology adoption. If unobserved characteristics determine both the adoption decision and the welfare outcome, conditional independence assumption will be violated and PSM will not be an appropriate method (Rosenbaum, 2002). Given that some of our results are sensitive to hidden bias, robustness of the results was counter checked by estimating the ATTs using an endogenous switching regression.

### Endogenous switching regression

The robustness of results under different assumptions was assessed using the endogenous switching regression model. Endogenous switching regression can be used to correct for selection bias due to unobservable characteristics. Estimating the endogenous switching regression model requires that an exclusion restriction be imposed for the model to be identified. This is done by including in the participation equation variables that influence participation decision but have no effect on the outcome variable (Wooldridge, 2010). The selected instrumental variables must pass the validity test in that they are significant in the participation equation but are insignificant in the outcome equation (Di Falco *et al.*, 2013). This study used farming experience and gender of decision maker for bean/maize production as the instrumental variables. Following the regression test, the instrumental variables passed the validity test in the sense that they were significant in the participation equation but not significant in the outcome equation.

### 3.8.3. Estimated effect of technology adoption on yield, income, and food security

Table 58 shows results on effects of Average Treatment on Treated (ATT) of technology adoption (ATT) using the nearest neighbour and radius-matching estimators. The two matching estimators were used to check robustness of the PSM results. However, interpretation of ATT results is based on the radius-matching estimator.

The results show that adoption of NARO bean and maize technologies increased bean and maize yield by  $141\text{kg ha}^{-1}$  (19%) and  $414\text{kg ha}^{-1}$  (22%), respectively. Adoption of NARO bean technologies increased bean income, farm income and household income by UGX 709000, UGX 1143000, and UGX 1650000, respectively which represents an average increase of 80 percent, 37 percent, and 36 percent, respectively (Table 58). Additionally, the results show that adoption of NARO maize technologies increased maize income, farm income and household income by UGX. 661000; UGX 156000; and UGX 2083000, respectively which represents an average increase of 65 percent, 54 percent, and 48 percent, respectively. Also, based on the effect on household food consumption score (FCS), adoption of NARO bean technologies increased the FCS by 10 percent that means that technology adoption improved food security by 10 percent in relation to non-adoption.

Table 58: Estimates of average effects of NARO technology adoption

Output variable	Radius matching		Nearest neighbour matching	
	ATT	LCV (t)	ATT	LCV (t)
<b>Bean technologies</b>				
Yield (Kg/ha)	141** (52.16)	1.6	96.4* (33.13)	1.5
Bean income	709,399*** (154,664)	1.2	424,650* (218,577)	1.3
Total farm income	1,143,493*** (294,495)	1.2	1,144,509** (434,293)	1.6
Household income	1,650,486*** (396,201)	1.3	1,979,914*** (607,466)	1.5
Food security (FCS)	5.39*** (1.19)	1.9	6.94** (2.84)	1.3
<b>Maize technologies</b>				
Yield (Kg/ha)	414.4** (266)	1.5	440** (207)	1.6
Maize income	661,963*** (108,542)	1.2	762,086*** (265,944)	1.5
Total farm income	1,559,881*** (289,564)	1.3	1,651,449*** (604,007)	1.2
Household income	2,083,231*** (366,070)	1.5	1,734,828* (974,410)	1.3
Food security (FCS)	4.65*** (1.08)	1.6	-0.87 (3.87)	1.4

Note: Asterisks represent level of significance at the 99% (\*\*\*), 95% (\*\*) and 90% (\*) confidence levels. Values in parenthesis are standard errors. ATT means average treatment effects on the treated while LCV means lowest critical value. All income is captured in Uganda Shillings.

*“We now have things we have bought for our homes. Far much more than those days when we couldn't afford. We have purchased solar lamps, mattresses, beds, TVs, radios, household utensils, carpets. Our kids are going to school, and even getting treatment in case they are sick” (FGD, Bagezza, 24<sup>th</sup> February 2021).*

*“If you rent a big garden, you can sell and earn much more, yes most of us have increased our land parcels by renting. These days we get more money from growing these crops” (FGD, Sekanyonyi, 18<sup>th</sup> February 2021).*

Whereas there was evidence of increased income and productivity due to technology adoption, the increases were not maximised due to limited use of complimentary inputs as shown in Table 18. However, most farmers used improved seed.

*“We select varieties which can withstand drought and mature in a short time like Nambale omumpi and yellow, we were trained to use 50cm X 10 cm. We know that we are supposed to plant 2 seeds per hole, but monkeys affect the seedling at germination.” (Sekanyonyi FGD, 18<sup>th</sup> February 2021).*

Regarding food security, adoption of NARO bean technologies increased the FCS by 5.4 points, representing a 10 percent increase, which means technology adoption improved food security by 10 percent in relation to non-adoption. A comparable increase in FCS (4.7) was observed for adopters of improved NARO maize technologies (Table 58). The increase in food security is attributed to the

increased maize and bean yield and increased household income of technology adopters. This is in agreement with a similar study in South-Central Uganda which showed that higher maize and beans yields were associated with food security (Apanovich & Mazur, 2018). Other studies have also shown that total monthly income is positively correlated with HFIAS, implying that the higher the monthly income, the greater the likelihood of being food secure (Coleman et al., 2014). This is likely because households with higher monthly income have raised disposable income to purchase larger quantities and more diverse food types.

#### Effects of technology adoption based on endogenous switching regression

The summary of results from the endogenous switching regression (ESR) models is shown in Table 59. The findings showed that the correlation coefficients ( $\rho$ ) between the respective outcome equations and the selection equations were not significantly different from zero thus indicating absence of hidden bias. Based on the full information maximum likelihood endogenous switching regression model (Table 59), the evidence indicates that adoption of improved NARO bean and maize technologies had a positive and significant impact on food security and income (bean or maize income, total farm income, and total household income).

Using the ESR model which controls for hidden selection bias (and compare with PSM results in parenthesis), the results further confirm that adoption of NARO bean technologies increased bean income, farm income and household income by about 55 percent (80%), 31 percent (37%), and 31 percent (36%), respectively. Adoption of improved NARO bean technologies also improved the food security.

A similar pattern of effects was observed for adoption of improved NARO maize technologies. Their adoption increased the maize income, farm income and household income by 64 percent (65%), 27 percent (54%) and 70 percent (48%), respectively. Adoption of the technologies also increased household food security.

Table 59: Summary of ATT from switching regressions

Variable	Improved NARO bean technologies	Improved NARO maize technologies
ATT, food consumption score	6.17(0.36) ***	4.72(0.71) ***
$\rho_1$	22.95(1.23)	24.07(1.59)
$\rho_2$	23.17(1.94)	28.13(4.8)
$\rho_3$	0.345(0.22)	-0.51(0.28)
$\rho_4$	-0.399(0.26)	-0.76(0.16) **
ATT, log beans or maize income	0.547(0.077) *	0.64(0.10) ***
$\rho_1$	4.3(0.14)	4.81(0.14)
$\rho_2$	3.2(0.15)	5.8(0.36)
$\rho_3$	0.04(0.19)	0.14(0.14)
$\rho_4$	0.12(0.25)	-0.17(0.23)
ATT, log farm income	0.307(0.048) ***	0.26(0.05) ***
$\rho_1$	1.88(0.06)	2.56(0.08)
$\rho_2$	1.61(0.06)	2.46(0.14)
$\rho_3$	0.15(0.12)	-0.98(0.005)
$\rho_4$	-0.06(0.16)	-0.001(0.88)
ATT, log total household income	0.311(0.04) ***	0.709(0.06) ***
$\rho_1$	1.79(0.62)	2.08(0.06)
$\rho_2$	1.69(0.72)	2.52(0.14)
$\rho_3$	0.08(0.14)	0.04(0.16)
$\rho_4$	-0.063(0.16)	-0.015(0.42)

Note: Statistical significance at the 99% (\*\*\*), 95% (\*\*) and 90% (\*) confidence levels. Figures in parentheses are standard errors.  $\rho_i$  is the correlation coefficient between the outcome and selection equations and  $\sigma$  is the standard deviation of the error term of the equation. A statistically significant correlation coefficient implies presence of selection bias.

Overall, the findings reveal that there are significant positive effects on income and food security due to adoption of both bean and maize technologies. Thus, results from endogenous switching regression are consistent with PSM results, which indicated that adoption of improved NARO bean and maize technologies increased maize and bean income, farm income and total household income. Key attributes of improved NARO bean and maize technologies that were reported by the farmers to contribute to increase household income include higher yields, drought tolerance, pest and disease resistance, better taste, and early maturity.

The results suggest that adoption of improved agricultural technologies has the potential to significantly increase farm and household income and food security. The evidence reinforces the dire need for increased support to agricultural research and dissemination of improved technologies. These technologies have potential to improve rural household welfare and contribute to agricultural transformation for long-term national economic development.

In addition to developing and disseminating the appropriate technologies, emphasis should be put on training farmers to use the complimentary inputs and practices to get the full benefit of the improved varieties. This calls for further strengthening of research-extension-farmer linkages.

### 3.9 Contribution of NARO research to the economy

#### 3.9.1 Introduction

Investment in the development and dissemination of improved beans and maize technologies by NARO over the past 5 years has resulted into increased adoption of the technologies, increased yield and high farm level returns among beans and maize farmers in Uganda. Whereas the research outputs are known, there was need to evaluate the economic returns on the investments of beans and maize research and development programmes in the country. In this study, the economic rationale for the evaluation of beans and maize research and development programmes by NARO was to improve efficiency in allocation of resources, through generation of the information for evidence-based decision-making. As public investment in agricultural research dwindles, there is need to further focus on efficiency to which funds are allocated. Decision makers require information on research payoffs to assess alternative uses of public funds. Alston (2010) remarked that to maximise the social value of project outputs, resources should be allocated where their benefit is greatest at the margin of expenditure. He recognised that at the aggregate level, the use of research and development evaluation provides a basis for optimising levels of investment in research and development.

A fundamental decision concerns the scale of overall investment in research and development. Both underinvestment and overinvestment need to be avoided: underinvestment in research and development of a crop like beans and maize may result in foregoing potential output and associated welfare gains to the society, while overinvestment could result in sacrificed output and associated welfare losses due to misuse of resources. Evenson (1988) argues that a major value of economic evaluation of past research and development in agriculture has been to demonstrate the exceptionally high returns to several agricultural research programmes and the substantial underinvestment in agricultural research, both at national and international level.

The study aimed to establish the economic returns to investment in the development and dissemination of NARO's beans and maize technologies over the study period. It is envisaged that by calculating rates of return to the beans and maize research and development activities in Uganda, will fill the gap in current knowledge about returns to the country's agricultural research and development.

#### 3.9.1 The Economic impact of improved beans and maize technologies

##### Economic impact of bean technologies

The internal rate of return to beans research and development has been examined and estimated at 43 percent (Table 60).

These results imply that investment in bean research and development has been successful and profitable to the beans farming community. In addition, it is argued that beans research program would increase its effectiveness and profitability by further addressing household needs, through focusing on appropriate beans varieties that provide food security and increase yield. More so, clear indicators of the profitability to beans farmers accruing from the investment in beans research and development in Uganda are the favourable benefit-cost ratio of 10.80 with net present value (NPV) showing net surplus of USD 633.5 Million by 2020, a few years after the investment in the crop. The NPV has substantially grown from 250 million dollars registered between 1986 and 2009 (CIAT, 2008). The IRR value of 43 percent indicates that the returns to beans research and development were above the current bank-lending rate in the country of between 17 to 24% (good payback from investment in bean research). It further indicates that IRR from investment in bean research grew from 39% reported during an earlier impact study conducted (CIAT, 2008). The economic returns (NPV and IRR) in beans surpassed 30% (IRR) and between US\$23 million and US\$67 million reported in sweet potato (Fuglie, 2007). This was not surprising for the fact that beans have moved from being a subsistence crop for household consumption to a tradable commodity.

#### Economic impact of maize technologies

Similarly, the internal rate of return (IRR) to maize research and development programs in Uganda was examined and estimated at 41 percent (Table 59). These results suggest that investment in maize research and development has been successful and profitable to the maize farming community. Maize research program can therefore increase its effectiveness and profitability by addressing consumer needs and focusing on appropriate maize varieties with high productivity. Further clear indicators of the profitability to maize farmers accruing from the investment in maize research and development in Uganda are benefit-cost ratio of 4.5 with net present value (NPV) showing net surplus by 2020 of USD 1.254 Billion a few years after the investment in the crop.

This result indicates that investment in R&D for maize is viable. The Internal Rate of Return (IRR) showed high value of approximately 41 percent, which is above the current bank-lending rate in the country between 17 to 24 percent. Three scenarios, however, affected the performance of the enterprise: (i) low adoption of full technology package, i.e., improved new varieties, good agronomic practices, and complementary inputs (fertilizer and pesticides for fall armyworm control) affected returns to investment from the enterprise. (ii) Outbreak of fall armyworm also affected yield performance of the enterprise between 2018 and 2020 and (iii) fluctuations in prices over the period

**Table 60: Average economic rate of return of improved beans and maize technologies**

Category	Annual mean (US\$ Million)				
	2016	2017	2018	2019	2020
<b>Bean research</b>					
Total costs	53.92	89.48	137.42	121.36	149.69
Gross benefits	184.12	300.69	335.59	276.22	288.05
Net benefits	130.20	211.20	198.17	154.86	138.36
PV at 10%	118.37	174.55	148.89	105.77	85.91
NPV at 10%	633.5				
IRR	43.42%				
BCR	10.80				
<b>Maize research</b>					
Total cost	86.385	66.851	47.810	73.990	65.016
Gross benefits	322.46	409.60	655.38	496.94	502.76
Net benefits	214.61	283.27	456.48	288.88	271.80
PV at 10%	136.08	228.02	420.56	238.35	231.43
NPV at 10%	1,254				
Internal Rate of Return	41.20%				
Benefit - Cost ration (BCR)	4.46				

Consumer price index (2016= as base year)

### 3.9.2 Contribution to consumer surplus

#### The Impact of improved bean and maize technologies on the economy

This study estimated the aggregate economic benefits through the economic surplus model (Alston, Norton, & Pardey, 1996). Improved bean and maize technologies are expected to increase yield, reduce yield losses, and reduce the cost of production. The adoption of the high yielding technologies increases the marketed surplus and reduces the per-unit cost of production. This technological change shifts the supply function downward which results in the increase of quantity sold and a price decrease, both at the aggregate level. Thus, producers of the improved bean and maize technologies gain from selling larger quantities and the consumers benefit from the fall in price. This results in aggregate gain to the national economy.

The study used a closed economic surplus model to estimate the measures of impacts of the different improved maize and beans technologies for a period of 10 years (2010 – 2020). The results of the Economic Surplus (ES) analysis indicate that sizable research benefits are generated by adopting the technologies. These benefits accrue mostly to the producers largely due to an increase in market surplus. The estimated national economic benefits of adopting improved maize technologies are about US\$ 22 million, US\$ 45 million, and US\$ 70 million at adoption rate of 25 percent, 50 percent, and 75 percent respectively (Table 61). Similarly, results in Table 61 show an increase in benefits with increased adoption levels for beans technologies at US\$ 4 million, US\$ 8 million and US\$ 13 million.

The results match with the findings of several studies on the economic benefits of agricultural research (Moyo, Norton, & Alwang, 2004; Pemsil & Staver, 2014). The sensitivity analysis showed that the aggregate benefits of the improved technologies are robust to variation in adoption ceilings.

The results in Table 61 show that the economic benefits that accrue from improved maize technologies are greater than those for beans due to the larger area under production for maize technologies and a higher adoption rate.

**Table 61: A comparison of research benefits for different adoption levels**

Crop	Means (US\$)			
	Adoption rate (%)	Consumer Surplus	Producer Surplus	Economic Surplus
Maize		63,264,047.23	60,561,339.15	94,896,070.85
Beans		11,370,517.74	11,015,389.73	17,055,776.61
<u>Sensitivity Analysis</u>				
Maize	25	14,802,496.28	14,633,577.02	22,203,744.42
	50	30,280,669.57	29,604,992.55	45,421,004.36
	75	46,434,519.89	44,914,246.60	69,651,779.84
Beans	25	2,709,456.43	2,687,260.93	4,064,184.65
	50	5,507,694.87	5,418,912.86	8,261,542.30
	75	8,394,715.30	8,194,955.80	12,592,072.95

Source: NARO Secondary and Primary data

### 3.10 Good practices for improvement of livelihoods

The National Development Plan (NDP III) is themed on agro-industrialization for transformation and under the agricultural sector, with focus to increase production and productivity as one of the contributors to agro-industrialization. To achieve these, agricultural plans of government and nongovernment organizations in development need to observe some good practices for positive impact in the medium term. This study provides evidence that generation and promotion of agricultural technologies will make a significant contribution to improvement of livelihoods and contributes significantly to national economic development.

#### Production and productivity

This study illustrates that NARO technologies have increased production and productivity. The evidence shows that adoption of improved NARO technologies increased production by about 20 percent while productivity increased by 19 percent for adopters of bean and 22 percent for adopters of maize technologies. Whereas adoption of NARO bean and maize technologies increased production and productivity, the increases were still below the yield potential expected by researchers, and this scenario was attributed to limited use of complimentary inputs. Therefore, to get the full

potential of NARO technologies for increased production, productivity and income of farmers, interventions should promote a full technology package, including improved varieties, management practices, complimentary inputs, and dissemination of relevant information on the technologies from research.

### Income

The evidence shows that farmers who adopted bean and maize technologies had higher incomes compared to their counterparts. The impact assessment shows that use of the improved technologies increased household income by UGX 1650000 (36 percent) for bean farmers and UGX 2083000 (48 percent) for maize farmers. Given that most of the poor in Uganda reside in rural areas, where agriculture is the main economic activity, efforts towards agricultural transformation must be cognizant of the effect of agricultural technologies on household incomes. Since, income directly indicates poverty levels, the effort to improve household income and reduce poverty should be coupled with technology promotion among farmers.

### Food security

Generally, most of the households were found to be food secure. The study revealed that adopter households were more food secure (76%) compared to the nonadopters (63%) based on food consumption grade which underscores the contribution of improved technologies to food consumption and grades. Results indicate that there was a high weekly consumption of maize and beans, indicating the importance of the two crops to household food security. Also, the impact assessment reveals that adoption of improved technologies reduces likelihood of food insecurity by about 10 percent. Therefore, agricultural technology development and dissemination, especially for beans and maize, should comprise an important component of the national food security strategy and accordingly be supported.

### Implications for the economy

Development of agricultural technologies requires significant investment by government and development partners. In Uganda, research outputs from NARO are a public good and many technologies have been released for farmers to adopt and contribute to improvement of their incomes. The overall outcome is improvement in livelihoods of Ugandans. The results indicate that the research and dissemination of improved NARO's beans and maize technologies during the 2016 to 2020 period was productive and profitable. The result also indicates that IRR from investment in bean research was 43 percent from 39 percent reported in an earlier impact study (CIAT, 2008). Generally, the economic returns (NPV and IRR) in beans surpassed 30 percent (IRR) and between US\$ 23 million and US\$ 67 million reported in sweet potato (Fuglie, 2007).

This high profitability of the investment in beans and maize in the country can be attributed to the massive investment by NARO, CGIAR centres and complementary organisations in beans and maize technology generation and promotion which resulted into the release and dissemination of more than 20 and 10 improved varieties of beans and maize respectively over the past 10 years: and to the technology acceptability and adoption by farmers.

It's however worth noting that the successes of beans and maize technology generation and dissemination were due to the joint contribution of complementary organisations and CGIAR centres. This implies that when research develops better varieties, there is need to have efficient testing and transfer systems to enhance adoption in time. This complementarity is likely to improve the impact of research and development on crop production. The contributions of non-research institutions to the technology development and transfer process are essential and interdependent. They need to share the credit for the benefits resulting from development and adoption of improved beans and maize varieties. It would have therefore been vital to include such costs when calculating the IRR to investment in research to avoid overstating return to research that may serve as a wrong guide to policies. This may mask additional investments needed to facilitate adoption of technology by farmers, which consequently may affect estimation of the economic feasibility of the research project. However, this was not possible due to lack of information from other complementary research partners.

The study recognises the contribution of technological change to beans and maize productivity in Uganda. This implies that the generation of such technologies through agricultural research is important as an economic activity to which scarce resources can be devoted and measurable output achieved. Examination of the areas under new varieties on sampled farms shows that there has been rapid adoption and high demand for improved maize varieties. Rates of return to investment in this beans and maize research and dissemination were estimated at 43 percent and 41 percent, respectively. Key elements leading to this success are the development of a technology that meets a specific farmer need but also satisfies farmers' other criteria, with rapid multiplication, distribution, and uptake. Whereas the IRR results may not be so important, the high and positive returns demonstrate the profitability of investments in beans and maize research and development in the country. However, we should resist the conclusion that all agricultural research would show such payoffs (Scobie and Posada, 1985) since the literature is not replete with evaluations of failures.

The positive economic returns observed were attributed firstly to newly released high yielding varieties to the farming communities. Secondly, due to the increase in production of new varieties as indicated by increment in area under improved varieties from 35 percent (2006) to approximately 60 percent currently (adoption level increase from 50 percent to 79 percent). This achievement was made despite the setbacks, which were attributed to the low bean productivity (yield) in the Northern and Central region, poor weather variability which affected production as well as the COVID19 (2020) which affected access to yield enhancing inputs by smallholders.

This study is open to criticism on several issues; the most noticeable ones can be drawn on the costs excluded from the analysis which may overstate the returns to investments. Furthermore, the data on which the estimations were based involved several approximations. Sensitivity analysis may be conducted to determine the performance of the projects under different cost assumptions. Despite these limitations, the general results hold that the investment in beans and maize research and development in Uganda have yielded large, positive IRR and can be judged to be worthwhile, which suggest that beans and maize research should have high priority in national plans.

## 4.0 CONCLUSIONS

### 4.1. Key message

This study set out to estimate the impact of NARO technologies on household welfare and contribution to the economy. The findings demonstrate that technology adoption has significant benefits to households in the farming communities. Farmers who adopted improved technologies released by NARO were found to have better outcomes from agricultural activity compared to the nonadopters. In the case of beans and maize farmers, adopters had higher production, higher productivity, higher incomes, and food security. The results also reveal that benefits from investment in R&D are positive and significant. The high payoff estimated in this study is in conformity with agricultural productivity of successful research and development reported elsewhere.

#### Adoption of improved technologies

The findings of this study provide evidence that there is a high level of farmer adoption of improved beans and maize technologies developed by NARO. The level of adoption has gradually increased over the past five years to 80 percent and 60 percent for improved maize and beans respectively. For instance, currently, the most popular NARO released bean variety is K132 followed by NABE 15 and NAROBAN 2 while the most popular maize varieties are LONGE 5 and LONGE 10H. The farmers attributed the increased adoption of improved varieties to their traits such as higher yield, better marketability, palatability, and easy of cooking, shorter maturity period and tolerant to diseases. Although the level of adoption of improved beans and maize varieties slightly varied across the agro-ecological zones, the crops were homogeneously perceived as both cash and food security crops in all the zones. The findings further showed that most farmers accessed agricultural information through trainings conducted by government extension agents and radio programmes. However, the study also finds that use of productivity enhancing complementary inputs such as fertilizers, herbicides, and pesticides, is still low (below 50%) among maize and bean farmers in Uganda.

The study reveals adoption of improved bean and maize technologies was influenced by access to information on NARO technologies, access to credit, technology attributes and farmer location in the adoption decision. This underpins the role of other actors such as government programmes in alleviating access to credit, in contributing to technology adoption and agricultural productivity.

#### Impact on productivity and income:

This study also provides empirical evidence that adoption of NARO bean and maize technologies significantly increased beans and maize production and productivity thus increasing household income. The study findings indicate that bean and maize income contributed between 27 and 34 percent to household income. Key attributes of improved bean and maize technologies that were reported by the farmers to contribute to increased household income include higher yields, drought tolerance, pest and disease resistance, better taste, and early maturity. These results indicate the importance of the crops to the household income of bean and maize farming households in Uganda.

Whereas there was evidence of increased income and productivity due to technology adoption, the increases were limited by low use of complimentary inputs. Many farmers were using the improved seed but not the recommended agronomic practices such as line spacing, seed rate, pests and disease control, fertilizer usage, among others, thus limiting the full potential of the technologies which perpetuates wider yield gaps between potential and actual farmer yield.

#### Impact on food security

Findings of this study indicate that bean and maize farming households were highly dependent on the two crops for their food security. A large percentage of the bean and maize farmers consumed beans and maize on at least 3 days in a week thus contributing about 53 percent and 43 percent of the required energy intake for the active women and men, respectively. The study revealed that an average sized household (6 members) consumed at least 10 kg of maize and about 8 kg of beans per week. Additionally, the study findings reveal that adoption of improved NARO bean and maize technologies increased household food security. The increased food security is attributed to not only consumption but also increased yield and household income associated with bean and maize technology adoption.

#### Impact on gender equity

Farmers reported that adoption of NARO technologies such as, early maturing varieties, herbicides and line planting reduced women's workload thus giving them more free time for rest and engagement in other developmental activities. They cited NAROBAN 1, 3 KI32, NABE 16, 17 and LONGE 4, 5 and LONGE 7H maize varieties with special attributes such as early maturity noting that the varieties spent a shorter time in the field (3months) hence reduction in the amount of weeding's in a season. It was noted that line planting of maize and beans made weeding of maize and beans less labour intensive.

The study reveals that many of the farmers (male and female) had joined agricultural-related groups such as farmers' savings, bean and maize production, agro-inputs dealers, and marketing groups. It was revealed that joining such groups enabled members to easily access credit, skills, and information (about markets, best agronomic practices, and improved varieties). In addition, they can collectively bargain for better prices for their produce. The results further indicate an increased role of women in formal leadership in groups. The leadership of women especially was profound in groups of savings and credit, seed store and marketing. There was a high trust for women in savings and credit groups as women were seen to be transparent, sincere, and trustworthy.

#### Contribution to national economy

The study demonstrates that there are positive economic returns from investment in beans and maize research and technology dissemination programs in Uganda. The estimated national economic benefits of adopting improved maize technologies are about US\$ 22 million, US\$ 45, and US\$ 69 at adoption rate of 25 percent, 50 percent, and 75 percent respectively. These benefits accrue mostly to the producers largely due to an increase in market surplus.

## 4.2 Recommendations

Considering the evidence presented by this study, investment in research and development has significant welfare benefits both at micro and macro levels and to contribute to national objectives in the NDP III and the current PDM frameworks for medium term transformation of Uganda, the following is suggested for policy.

- These results indicate that extension agents and radio are the most important channels through which farmer's access agricultural information. Therefore, research and development agents can emphasize dissemination of technology information through these channels to reach more farmers. There is need, however, to engage mobile phones and other e-platforms in this effort.
- The evidence suggests that farmer technology adoption is strongly influenced by access to extension information, technology attributes and farmer location. Similarly, seed availability was cited among the top three indicative drivers of variety choice. Therefore, NARO technology development should be complemented with a robust information and technology dissemination strategy. This can be achieved through facilitating access to quality planting materials and seed for next planting season and by strengthening research-extension-farmer interface.
- Respondents however indicated that they had limited access to most formal institutions due to unfriendly loan terms such as: collateral, guarantors, existence of bank accounts and high interest rates. Although Savings and Credit Cooperative Organisations (SACCOs) were the most dominant sources of credit, less than 10 percent of the respondents belonged to them. Therefore, given the importance of credit in facilitating access to agricultural inputs, there should deliberate policy measures for strengthening SACCOs institutional capacities to efficiently provide readily accessible credit to smallholder farmers
- The results suggest that adoption of improved agricultural technologies has the potential to significantly increase farm and household income and food security. Given the above evidence government should increase support for agricultural research and dissemination due to its potential to improve rural household welfare and contribution to agricultural transformation for long term national economic development, especially for countries like Uganda, where about 70 percent of households depend on agriculture for their livelihood and where agricultural products contribute about 22 percent to national GDP. Therefore, increasing funding to research and the agricultural extension apparatus is likely to increase MAAIF and NARO capacity to develop and disseminate new technologies for improved farmer livelihoods and national economic development
- The results indicate that although technology adoption increased productivity, it was still far below the research production output. This suggests that in addition to developing and disseminating the appropriate technologies, emphasis should be put on training farmers to use the complimentary inputs and practices to get the full benefit of the improved varieties. This calls for further strengthening of research-extension-farmer linkages

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## ANNEXES

### Annex 1: NARO agro-ecological zones and their districts

#	NARO Zone	Districts
1.	Abi	Arua, Nebbi, Moyo, Obongi, Maracha, Adjumani, Madi Okolo, Obongi, Zombo, Yumbe, Koboko, Pakwach
2.	Buginyanya	Mbale, Sironko, Manafwa, Bulambuli, Bududa, Namisindwa, Budaka, Butaleja, Tororo, Pallisa, Butebo, Busia, Kibuku, Bukwo, Kween, Kapchorwa, Namutumba, Kaliro, Luuka, Kamuli, Jinja, Mayuge, Iganga, Bugiri, Namayingo, Buyende
3.	Bulindi	Hoima, Masindi, Kikube, Bulisa, Kiryandongo, Kagadi, Kakumiro,
4.	Ngetta	Lira, Kole, Oyam, Omoro, Dokolo, Alebtong, Otuke, Amolatar, Apac, Kwania, Gulu, Amuru, Nwoya, Kitgum, Lamwo, Pader, Agago
5.	Mukono	Bukomansimbi, Kiboga, Kyankwanzi, Lwengo, Mityana, Mubende, Nakaseke, Buikwe, Butambala, Buvuma, Gomba, Kalangala, Kalungu, Kampala, Kassanda, Kayunga, Luwero, Masaka, Mpigi,
6.	Kachwekano	Kabale, Rubanda, Rukiga, Kisoro, Rukungiri, Kanungu,
7.	Mbarara	Buhweju, Bushenyi, Ibanda, Isingiro, Kazo, Kiruhura, Lyantonde, Mbarara, Mitooma, Ntungamo, Rakai, Rubirizi, Rwampara, Sembabule,
8.	Nabuin	Abim, Amudat, Amuria, Bukedea, Kaabong, Kaberamaido, Kapalebyong, Karenga, Katakwi, Kotido, Kumi, Moroto, Nabilatuk, Nakapiripirit, Napak, Ngora, Serere, Soroti
9.	Rwebitaba	Bundibugyo, Bunyangabo, Kabarole, Kamwenge, Kasese, Kitagwenda, Kyegegwa, Kyenjojo, Ntoroko

**Annex 2: Sample size across the districts**

<b>ZARDI</b>	<b>District</b>	<b>Observations</b>	<b>Proportion</b>
<b>ABIZARDI</b>	Arua	56	0.039
	Koboko	47	0.033
	Yumbe	48	0.033
	Zombo	48	0.033
<b>BUGIZARDI</b>	Bugiri	56	0.041
	Bukwo	57	0.039
	Bulambuli	62	0.043
	Iganga	46	0.032
	Sironko	52	0.036
	Tororo	58	0.040
	<b>BUZARDI</b>	Kakumiro	21
	Kikube	40	0.028
	Kiryandongo	24	0.017
	Masindi	20	0.014
<b>KARZARDI</b>	Kabale	32	0.022
	Kisoro	18	0.012
	Rubanda	37	0.026
	Rukiga	15	0.010
<b>MUZARDI</b>	Bukomasimbi	65	0.045
	Kiboga	70	0.048
	Kyankwanzi	75	0.052
	Lwengo	71	0.049
	Mityana	76	0.053
	Mubende	70	0.048
<b>NGETTA</b>	Nakaseke	69	0.048
	Dokolo	14	0.010
	Kole	59	0.042
	Lira	47	0.032
	Omoro	46	0.032
	Oyam	43	0.030

## Annex 3: Farmer characteristics by main crop enterprise

Variable	Proportion of farmers				
	Overall	Bean	Maize	Female	Male
Respondent is household head (%Yes)	.716	.644	.783	.904	.663
Male headed HH	.783	.741	.823	.000	1.00
Marital status of HH head					
Divorced	.033	.038	.027	.134	.004
Married	.830	.81	.850	.350	.964
Never married	.052	.058	.046	.162	.021
Widowed	.085	.093	.077	.354	.011
Education level of HH head					
Diploma	.037	.028	.045	.006	.045
No formal education	.071	.078	.064	.197	.035
Nondegree tertiary education	.035	.033	.037	.019	.039
Primary schooling	.504	.516	.494	.519	.500
Secondary schooling "A" level	.042	.047	.038	.016	.050
Secondary schooling "O" level	.287	.280	.292	.229	.302
University level	.025	.018	.031	.013	.028
Main occupation of HH head					
Crop farming	.842	.836	.848	.869	.835
Business	.017	.024	.011	.029	.014
On-farm labour for a wage	.001	.001	.000	.000	.001
Forestry	.001	.001	.000	.000	.001
Formal employment	.03	.024	.037	.013	.035
Livestock farming	.01	.016	.005	.01	.011
Mixed farming	.076	.071	.081	.064	.080
Off-farm labour for a wage	.004	.006	.003	.003	.004
Transporter	.003	.004	.001	.003	.003
Other	.015	.017	.014	.01	.017
HH head belongs to a group	.732	.729	.735	.717	.737
Seed production	.211	.227	.195	.160	.224
Farmer research group	.096	.113	.081	.102	.095
Savings & credit	.047	.054	.041	.031	.052
Funeral	.739	.685	.790	.804	.721
Tree planting	.094	.136	.053	.107	.090
Soil & water conservation	.007	.004	.009	.004	.007
Religious group	.003	.002	.004	.004	.002
Input credit	.034	.033	.035	.049	.030
Others group	.007	.008	.006	.013	.005
Others group	.074	.072	.076	.031	.085
HH benefited NARO technology	.599	.572	.624	.551	.612

**Annex 4: Household qualities**

Variable	Overall (N=1445)	Na.	Ad.	Bean farmer	Maiz e
<b>Water source</b>					
Well in compound	0.016	0.018	0.015	0.020	0.012
Piped/Tap water inside house	0.075	0.053	0.084	0.062	0.087
Communal tap/well/borehole	0.745	0.742	0.746	0.711	0.777
River/stream	0.131	0.153	0.122	0.160	0.104
Water tank at home	0.033	0.034	0.033	0.047	0.020
<b>House lighting</b>					
Candle/wicker lamp	0.010	0.014	0.008	0.016	0.004
Paraffin/hurricane lamp	0.030	0.043	0.025	0.033	0.028
Gas lamp	0.123	0.114	0.127	0.135	0.112
Torch	0.006	0.000	0.008	0.007	0.004
Solar	0.091	0.130	0.073	0.098	0.084
Electricity	0.652	0.648	0.653	0.622	0.681
Biogas	0.087	0.050	0.103	0.089	0.085
Other	0.001	0.000	0.002	0.001	0.001
<b>Have a radio/TV</b>					
None	0.226	0.306	0.192	0.256	0.198
Only radio	0.531	0.521	0.535	0.513	0.548
Only TV	0.045	0.032	0.051	0.045	0.045
Both RADIO & TV	0.198	0.142	0.222	0.186	0.210
<b>Toilet facility</b>					
No toilet	0.006	0.007	0.006	0.008	0.004
Uncovered pit latrine	0.280	0.288	0.276	0.290	0.269
Ecosan	0.007	0.014	0.004	0.006	0.008
Covered pit latrine	0.573	0.573	0.573	0.576	0.570
VIP latrine	0.131	0.116	0.137	0.118	0.143
Flash toiled	0.003	0.002	0.004	0.001	0.005
<b>Mobile phones at home</b>					
None	0.071	0.084	0.066	0.078	0.065
One	0.386	0.489	0.342	0.401	0.372
Two	0.392	0.311	0.427	0.387	0.396
Three & more	0.151	0.116	0.166	0.135	0.166
<b>School going members (aged 6-18)</b>					
None	0.188	0.249	0.162	0.195	0.181
Present	0.786	0.737	0.807	0.785	0.788
No member aged 6-18	0.026	0.014	0.031	0.020	0.031
<b>Have vehicle</b>					
No	0.739	0.822	0.703	0.768	0.712
Yes, bicycle/motorcycle	0.242	0.167	0.275	0.218	0.265
Yes, motorcar	0.019	0.011	0.022	0.014	0.023
<b>Cooking fuel</b>					
Firewood	0.857	0.849	0.860	0.846	0.867
Charcoal	0.085	0.073	0.090	0.081	0.089
Crop/animal residue	0.002	0.002	0.002	0.001	0.003
Biogas	0.001	0.002	0.001	0.001	0.001
Paraffin	0.009	0.009	0.009	0.010	0.008
LPG/Gas	0.001	0.002	0.001	0.000	0.003
Electricity	0.006	0.005	0.006	0.008	0.003
Solar	0.037	0.057	0.028	0.048	0.026
Briquettes	0.002	0.000	0.003	0.004	0.000
Briquettes	0.002	0.000	0.003	0.004	0.000

## Annex 5: Rating of practices on production

l2q02_label	Obs.	Mean	SD	Min	Max
Adjusting planting dates	68	4.500	.838	2	5
Agro-forestry	28	3.893	1.133	1	5
Climate smart practices	2	3.500	.707	3	4
Crop diversification	51	3.843	.925	2	5
Drought tolerant animal breeds	162	4.284	.830	1	5
Drought-tolerant plant varieties	54	3.648	1.200	1	5
Early maturing varieties	316	3.994	.891	1	5
Fodder preservation	476	3.971	.868	1	5
Food processing & VC management	14	3.786	1.369	1	5
Improving soil moisture	12	4.333	1.155	1	5
Increasing use of climate forecast information	62	3.694	.916	2	5
Integrated pests & disease management	5	3.800	1.304	2	5
Kitchen gardening	106	3.906	.900	2	5
Mechanization	37	4.378	.893	1	5
Mixed farming	45	4.089	.793	3	5
Mixed cropping/ Intercropping	109	4.138	.887	2	5
Other practice	226	3.628	.911	1	5
Protection & restoration of ecosystem	11	4.000	.632	3	5
Protection & restoration of ecosystem	9	4.333	.500	4	5
Small scale irrigation systems	26	3.808	1.096	2	5
Solar technology	4	3.250	1.500	2	5
Soil & water conservation	105	3.867	.951	1	5
Tree planting;	72	3.778	1.038	1	5
Use of Hybrid and quality seed	205	4.298	.763	2	5
Fertilizer application	262	4.328	.787	1	5

Note: Scale is 1-5 (1 for least beneficial & 5 very beneficial)

**Annex 6: Alternative crops grown**

Crop	Percent of farmers & crop rank (N=496)			
	First	Second	Third	Fourth
Maize	37.7	32.9	14.	6.9
Beans	35.5	35.3	12.5	8.9
Coffee	12.7	7.9	12.9	8.1
Bananas	8.7	10.3	20.2	16.7
Cassava	1.8	3.0	13.3	20.6
Irish potato	0.8	1.2	3.4	3.0
Groundnut	0.6	1.8	6.1	6.1
Other	0.6	0.4	0.2	0.4
Sweet potato	0.6	2.8	7.7	15.7
Tomatoes	0.4	1.2	2.2	1.2
Malakwang	0.2	0.0	0.0	0.0
Onions	0.2	1.0	0.0	2.0
Sugar cane	0.2	0.6	0.6	0.0
Egg plant	0.0	0.0	0.2	0.4
Finger millet	0.0	0.4	1.0	1.0
Cabbage	0.0	0.2	0.2	0.2
Onions	0.0	0.0	1.0	0.0
Vanilla	0.0	0.0	0.6	0.0
Pumpkin	0.0	0.0	0.2	0.0
Rice	0.0	0.4	0.0	0.20
Sesame	0.0	0.0	0.0	0.2
Sorghum	0.0	0.0	0.0	0.6
Soybean	0.0	0.2	1.4	0.6
Spider plant	0.0	0.0	0.0	0.4
Vegetables	0.0	0.0	0.6	1.2
Enswiga	0.0	0.2	0.0	0.0
Na	0.0	0.2	0.8	2.2
None	0.0	0.0	0.6	3.4

**Annex 7: Access to improved technology**

Mode of seed access	Proportion of farmers				
	Overall	Beans	Maize	Nonadopters	Adopters
Purchased	0.643	0.555	0.698	0.504	0.706
Seed aid	0.058	0.063	0.055	0.047	0.063
Barter exchange	0.020	0.027	0.015	0.033	0.013
Seed revolving scheme	0.023	0.039	0.012	0.026	0.021
Government supply	0.062	0.024	0.086	0.014	0.084
Own (saved) seed	0.383	0.518	0.299	0.602	0.283
Other (Donation,)	0.248	0.343	0.188	0.417	0.171

## Annex 8: Market participation and other-crop income

### Other-income crops

Crop	Percent of respondents		
	Overall	Adopters	Nonadopters
Bananas	23.9	24.1	23.3
Coffee	20.0	20.0	20.3
Cassava	19.6	19.3	20.3
Sweet potato	13.6	13.7	13.5
Groundnuts	8.2	8.1	8.6
Irish Potato	4.9	4.5	6.7
Tomatoes	2.0	2.2	1.2
Other	1.6	1.5	1.8
Finger millet	1.2	1.0	2.5
Onions	1.1	1.1	1.2
Soybean	0.9	1.0	0.6
Egg plants	0.6	0.7	0.0
Rice	0.5	0.4	0.0
Vanilla	0.5	0.6	0.0
Vegetables	0.5	0.6	0.0
Cabbage	0.3	0.4	0.0
Cocoa	0.2	0.3	0.0
Sorghum	0.2	0.3	0.0
Sesame	0.1	0.1	0.0
Spider plant	0.1	0.1	0.0

## Annex 9: Income from various crops

Crop	N	Mean	SD	Min	Max
Bananas	213	1010000	1530000	0	8000000
Cabbage	3	13333.33	7637.626	5000	20000
Cassava	174	265000	618000	0	5000000
Cocoa	2	672500	110000	595000	750000
Coffee	178	1890000	3620000	0	3.96e+07
Egg plants	5	314000	331000	40000	840000
Finger millet	11	65795.46	128000	0	400000
Groundnuts	73	472000	1020000	0	5800000
Irish Potato	44	765000	1180000	0	7200000
Onions	10	1290000	967000	400000	3200000
Other	14	3690000	6000000	0	2.25e+07
Rice	4	2460000	2400000	5	4675000
Sesame	1	420000	.	420000	420000
Sorghum	2	845000	841000	250000	1440000
Soybean	8	173000	340000	0	1000000
Spider plant	1	0	.	0	0
Sweet potato	121	143000	362000	0	2800000
Tomatoes	18	3110000	3350000	400	1.20e+07
Vanilla	4	7375000	1.03e+07	500000	2.25e+07
Vegetables	4	1097500	1330000	5000	3000000

## Annex 10: Percent of farmers with income from various livestock

Livestock type	Overall (N=1445)		Nonadopters		Adopters		Women		Men	
	2020	2016	2020	2016	2020	2016	2020	2016	2020	2016
Apiary	.001	.000	.000	.000	.002	.000	.000	.000	.002	.000
Bulls	.073	.051	.050	.027	.082	.062	.029	.025	.085	.058
Chickens	.379	.243	.356	.231	.388	.248	.331	.226	.392	.248
Cows	.310	.198	.269	.155	.328	.216	.239	.175	.330	.204
Donkeys	.001	.001	.000	.000	.002	.002	.000	.003	.002	.001
Ducks	.027	.017	.027	.016	.027	.017	.029	.013	.027	.018
Fish	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Goats	.383	.222	.384	.196	.383	.233	.318	.194	.401	.230
G-fowl	.003	.001	.005	.002	.002	.000	.003	.000	.003	.001
Oxen	.035	.025	.025	.025	.040	.025	.003	.006	.044	.030
Pigs	.289	.154	.265	.137	.300	.162	.309	.159	.284	.153
Rabbits	.014	.006	.014	.007	.014	.005	.01	.010	.015	.004
Sheep	.066	.027	.107	.046	.049	.019	.035	.013	.075	.031
Turkeys	.009	.006	.005	.000	.011	.009	.006	.010	.010	.005
Other livestock	.002	.002	.002	.005	.002	.001	.003	.000	.002	.003

### Annex 11: percent of farmers who produced livestock products

Livestock product	Proportion of farmers									
	Overall		Beans		Maize		Nonadopter		Adopter	
	2020	2016	2020	2016	2020	2016	2020	2016	2020	2016
Cow milk	.139	.080	.132	.071	.146	.089	.121	.064	.147	.087
Goat milk	.004	.001	.003	.001	.005	.001	.000	.000	.006	.002
Beef	.004	.001	.006	.000	.003	.001	.009	.000	.002	.001
Mutton	.003	.001	.003	.000	.003	.001	.002	.000	.003	.001
Skins	.001	.000	.000	.000	.001	.000	.000	.000	.001	.000
Eggs	.072	.044	.062	.041	.081	.046	.064	.048	.075	.042
Honey	.001	.000	.001	.000	.000	.000	.000	.000	.001	.000
Ghee	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Bongo	.001	.000	.001	.000	.000	.000	.002	.000	.000	.000
Butter	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Manure	.048	.020	.069	.025	.027	.015	.071	.027	.038	.017
Other	.001	.001	.000	.000	.001	.001	.000	.000	.001	.001
None	.002	.003	.001	.006	.003	.001	.002	.000	.002	.005

### Annex 12: estimated income from various livestock products

Livestock product	N	Mean revenue	N	Mean revenue	Test p-value
		2019		2016	
Livestock dung	26	1379769	16	561000	
Eggs	19	2272500	10	1147850	
Cattle milk	63	1880000	35	1156200	
Ghee	1	300000	-		
Goat milk	1	180000	-		
Honey & other products	1	1080000	-		

## Annex 13: Non-farm income sources

Variable	Proportion of farmers									
	Overall		Beans		Maize		Nonadopter		Adopter	
	2020	2016	2020	2016	2020	2016	2020	2016	2020	2016
Daily wage from farm	.024	.015	.034	.021	.015	.008	.034	.023	.020	.011
Daily wage from	.037	.024	.037	.023	.037	.024	.037	.016	.037	.027
Salary	.071	.060	.062	.048	.080	.070	.039	.046	.085	.066
Boda-boda	.028	.017	.024	.014	.031	.019	.021	.016	.031	.017
Beer brewing	.023	.018	.020	.020	.026	.016	.014	.007	.027	.023
Hunting	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Forest products	.011	.009	.007	.003	.015	.015	.011	.007	.011	.010
Remittances	.020	.016	.021	.016	.019	.016	.018	.021	.021	.014
Trade	.150	.098	.147	.085	.153	.110	.132	.084	.158	.103
Pension	.008	.003	.007	.003	.009	.004	.005	.000	.01	.005
Craft making	.003	.003	.006	.006	.001	.001	.009	.007	.001	.002
Transfers	.004	.000	.006	.000	.003	.000	.002	.000	.005	.000
Property income	.013	.008	.013	.008	.014	.008	.016	.014	.012	.006
Brick making	.013	.009	.011	.007	.015	.011	.009	.002	.015	.012
Quarrying	.001	.001	.001	.001	.000	.000	.002	.002	.000	.000
Mining	.001	.001	.001	.001	.001	.001	.002	.002	.001	.001
Fishing	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Carpentry	.008	.006	.010	.007	.007	.005	.005	.007	.01	.006
Land rents	.003	.001	.001	.000	.005	.003	.002	.002	.004	.001
Other source	.073	.044	.065	.038	.081	.050	.062	.037	.078	.048

## Annex 14: Comparison of FCS with food group consumption

Cluster	Prevalence	Mean of weekly number of days for consumption of foods								
		FCS	Staples	Pulses	Vegetables	Meats	Milk	Fruits	Sugars	Oils
<b>Overall</b>										
Poor	1	17.57	4	2	1	0	0	2	3	2
Borderline		36.4	5	3	3	1	1	3	4	4
Acceptable	71.8	67.7	6	5	5	2	2	4	6	5
<b>Nonadopters</b>										
Poor	1	17.8	3	2	2	1	0	1	1	1
Borderline		36.7	6	5	3	1	0	1	2	2
Acceptable	63.0	66.1	6	5	6	4	3	3	4	4
<b>Adopters</b>										
Poor	1	17.5	3	2	1	1	0	1	1	1
Borderline		36.1	5	4	4	1	1	2	3	3
Acceptable	75.6	68.3	6	5	6	4	3	3	5	5

Note: Poor food consumption score ranges from 0-28; Borderline is 28.5-42; Acceptable is  $\geq 42.5$



NARO Secretariat,  
Plot 11-13 Lugard Avenue.  
P. O. Box 295 Entebbe, Uganda.  
Or online at: <https://www.naro.go.ug>

