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Assessment of Agronomy, Agroforestry, Orchards, Grain Storage, and Postharvest Programs on Empowerment of Farmers in Rural Uganda

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Abstract

In Uganda, limited agricultural extensionists have always hampered the capacity development efforts of farmers, necessitating partnerships with local and international organizations. This study assessed the progress made by the Iowa State University Center for Sustainable Rural Livelihoods (CSRL) toward ending hunger in Uganda. The CSRL partners with Iowa State University Uganda Program and Makerere University in the capacity development of communities through interrelated livelihood education programs including agronomy, agroforestry, orchards, grain storage, and postharvest programs. We surveyed 454 households, of whom 48.2% had participated in extension education programs during the 2014–2018 assessment period. Primarily, these farmers trained mostly in micronutrient vegetable gardening, field agronomical practices, soils, composting, and postharvest/grain storage, least in land-use planning and marketing. The study found that trained households statistically significantly engaged in sack, keyhole, and kitchen gardening and used tarpaulins while drying crops. The study identified a general increase in trained households who cultivated grain amaranths, soybeans, common beans, high-iron beans, and groundnuts, probably due to training and provision of seeds of some crops by the program. Overall, most households engaged in the production of staple foods like sweet potatoes and cassava. Cultivation of cereals, millet, maize, and rice, was reduced between 2014–2017. The major challenges to crop production identified included soil infertility, striga weed infestation, and limited land (average of 3.54 acres). For sustainability, improving the monitoring implementation of agronomical practices is vital. Communities are encouraged to use the CSRL training centers as a hub for learning the principles of agronomy and postharvest management. These centers employ a mode of knowledge transfer and community empowerment, blending indigenous and scientific knowledge and involving the communities in planning education programs.

Introduction and Background

Agriculture is the backbone of the economy of Uganda, a significant source of food and fiber, and a foundation of agro-based industrial development efforts (Uganda Bureau of Statistics [UBOS], 2016). Over 50% of the agricultural activities are on a small scale characterized by low output, mainly for home

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consumption and any surplus for sale (UBOS, 2016). Over-reliance on nature with its catastrophic consequences like drought, infertility, and floods partially explains the low yield. This situation partially accounts for the high levels of food insecurity and malnutrition in Uganda ranked as "serious" on the global hunger index (von Grebmer et al., 2023). Moreover, the prediction of the "current path scenario" indicates that Uganda may not achieve food security by 2050 (Hedden et al., 2018). Such a scenario suggests a need for more approaches to capacity development in agrifood production systems and improving the structural functionality of intervention programs (Office of the Prime Minister [OPM], 2020) with public-private partners (Butler & McMillan, 2015).

Over the years, Uganda has adopted various extension education approaches chronologically to build the capacity of farmers. During the pre-independence period (i.e., before the 1960s), extension education was characterized by an authoritarian system executed by cultural chiefs on behalf of the British colonialists with interests in producing cotton and coffee for their industries (Semana, 1999). Toward the eve of independence (i.e., late 1950s) and after independence, a transfer of technology (ToT) model was adopted. In this model, a few extensionists were identified by authorities to train communities on demonstration farms (Opio-Odongo, 1992). The ToT system was also authoritative, and farmers had no contribution to the knowledge base; it was also bureaucratic and lacked accountability (Ssemakula & Mutimba, 2011), a precursor to the failure of an innovation model (Rogers, 2003).

The ToT model was further devastated by the political turmoil of 1970-1985 (Museveni, 2000), ushering in the Bretton Woods Institutions—The World Bank and International Monetary Fund (IMF) that introduced the structural adjustment policies (SAPs) to help developing countries out of poverty (Kreimer et al., 2000). A training and visit (T&V) approach was devised and adopted as a new extension education model in 1992 with the support of the World Bank after adhering to the SAPs (Anderson et al., 2006). The T&V model involved extension agents training specific farmers, and a follow-up was conducted. However, T&V was ineffective due to limited extensionists and concentration on large-scale rather than small-scale farmers. Feder et al. (1986) analyzed the T&V model in India and found similar results, though, in India, technological advancements influenced further growth of the T&V to benefit more farmers.

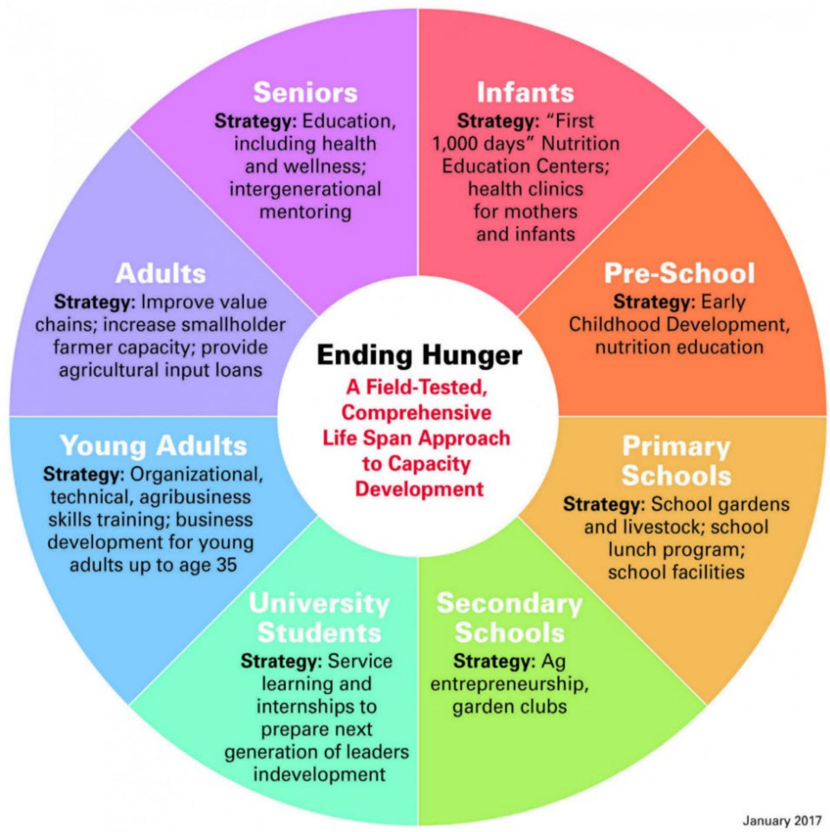
Although Uganda was among the first best performers in reforming its economy owing to the SAPs' first five years, by 1996, it was listed among the highly indebted poor countries [HIPCs] (Kreimer et al., 2000). As a condition for debt waiver from the World Bank, the HIPCs were asked to formulate poverty reduction strategy papers to cover 20 years from 1997–2017. Uganda drafted the poverty eradication action plan (PEAP) targeting a 10% decrease in absolute poverty (Ministry of Finance Planning and Economic Development [MFPED], 2000). PEAP embedded the plan for modernization of agriculture (PMA) to eradicate poverty by transforming subsistence into commercial agriculture. A new secretariat was created—National Agriculture Advisory Services (NAADS), to implement the activities of the PMA (Ministry of Agriculture Animal Industries and Fisheries [MAAIF], 2000). A farmer-to-farmer extension education approach was adopted, working in a decentralized governance format, where farmer groups were formed at the village through Sub-counties to District levels. Implementation was demand-driven, based on the community's needs, and communities participated in finding solutions. Financing was through crowdfunding from stakeholders, including government, donors, Nongovernmental organizations (NGOs), and farmers through cost-sharing.

However, during the launching of the farmer-to-farmer extension education model, the Uganda Nutrition and Food Council (UNFC) highlighted the limited number of extension agents as a problem in their capacity-building efforts (MAAIF & Ministry of Health [MoH], 2004). Since then, in 2003, the Ministers of Health and Agriculture appealed to the general public, including the NGOs and government organs, to pass the UNFC's Uganda Food and Nutrition Strategy (UFNS) policy framework. Upon passage of the UFNS, its investment plan was drafted, and the line Ministries, including Local Government, Health, Agriculture, Gender, Land, Justice, Finance, and The Office of the Prime Minister (OPM), committed full support to its implementation with the stakeholders (MAAIF & MoH, 2004). This process accounted for the public-private partnership ushered in by Iowa State University, a U.S. university through its Center for Sustainable Rural Livelihoods (CSRL) since 2003. CSRL aims to uplift the status of rural communities in Uganda through capacity development and to end hunger with funds from private benefactors (Butler & McMillan, 2015).

Iowa State University and The Center for Sustainable Rural Livelihoods in Uganda

The Center for Sustainable Rural Livelihoods (CSRL) envisions the development of responsible global citizens and thriving local communities that benefit from food and financial security (Butler & McMillan, 2015; Ikendi & Retallick, 2023a). This vision is achieved through a public-private partnership where it operates in a trio partnership with Makerere University and local NGOs. Between 2004 to 2014, the participating NGO was Volunteer Efforts for Development Concerns (VEDCO); this trio operated under the farmer-to-farmer model (Masinde, Butler et al., 2015) commensurate with the NAADS program of the government. Farmers were organized into small food security groups, formed constitutions, and elected their leaders (Sseguya et al., 2015). The groups worked with the government and CSRL/VEDCO extensionists to build capacity to improve food production. In 2014, Iowa State University Uganda Program (ISU–UP) assumed the role of a local participating NGO (Butler & Acker, 2015; Ikendi & Retallick, 2023a). In operationalizing ISU–UP, CSRL instituted the "comprehensive life-span approach to capacity development" model (Figure 1, adapted from CSRL, 2017). This approach touches the lives of all members, from pregnant to seniors, through interconnected livelihood education programs (LEPs) to develop their capacities towards food security (Ikendi, Owusu et al., 2023a; 2024) and nutrition security (Ikendi, Owusu et al., 2023b; 2023c).

Figure 1: *The CSRL Comprehensive Life-Span Approach to Capacity Development in Uganda.*



Although CSRL/ISU–UP has several LEPs, this article focuses on the interrelated programs of agronomy, agroforestry, orchards, grain storage, and postharvest technologies. The *agronomy program* works to improve access to extension education knowledge and quality diverse crop inputs to ensure food and financial security and reduce malnutrition. This program mainly serves households with at-risk-for-malnutrition mothers and children who are under rehabilitation and/or have been rehabilitated and have joined the food and nutrition security support groups (Ikendi, Owusu et al., 2023b; 2023c; Masinde, McMillan et al., 2015) and youth in-and-out of school through agricultural entrepreneurship, home, and school gardening programs with global service-learners from Makerere and Iowa State Universities (Banige et al., 2024a; 2024b; Ikendi, 2022; Ikendi, Retallick et al., 2023; Nonnecke et al., 2015). The agronomy program also serves the community to support knowledge acquisition and transfer—a precursor to diffusion and adoption of relevant agronomic practices to improve agricultural productivity (Rogers, 2003).

Depending on the available funds, the agronomy program provides some program-trained farmers and schools with planting materials including seeds of millet, soybean, grain amaranths, high iron beans, common beans, pumpkins, pigeon peas, cowpeas, green pepper, beetroots, maize; seedlings of collards, eggplants, garden eggs, spinach, tomatoes, and spring onions; vines of orange-fleshed sweet potatoes; cassava cuttings, banana suckers; cash crop seedling like cocoa, coffee, cashew nuts–supported by the government. Farmers and schools are also supported to set up herbaria with assorted herbs like oregano, basil, mint, and tobacco used for tea and herbal medicine for humans and livestock projects like poultry. Providing inputs ensures that household gardens have a variety of nutrient-dense crops to diversify diets (Ikendi, Owusu et al., 2024) and incomes from sales and ensure sustainability in production through seed multiplication. Additionally, for sustainability purposes, farmers are obliged to return to the program the equivalence of the seeds given to them after harvesting.

The *agroforestry and orchard* programs promote environmental education in schools (Ikendi, Retallick et al., 2023) and communities (Wokibula & Westgate, 2016). Schools incorporate agroforestry projects to protect school gardens as fences and for environmental conservation. High tensile barbed wire fences, for instance, are erected through which a living fence of *Euphorbia* and/or Kei-apple are planted. The bitter white sap of *Euphorbia* prevents animals from eating it and grows vigorously, establishing itself and creating a continuous intertwined fence. The thorny structures of Kei-apples are defensive against animals, and flowers attract both honey and native bees, supporting the development of global service-learning bi-national beekeeping projects in schools (Ikendi, Retallick et al., 2023). Relatedly, several agroforestry trees are promoted for planting with seedlings obtained from school tree nurseries. For example, *Calliandra calothyrsus* are planted to provide firewood, fodder, soil improvement, and stabilization through nitrogen fixation. Acacia woodlots are planted to provide fuelwood that supports school lunch programs. Other tree species planted include eucalyptus, *Markhamia lutea*, and *Terminalia* to provide firewood and timber. Orchards are also established in schools where students are engaged in raising nurseries and grafting of plants and fruits, including papaya, avocado, mangoes, guava, oranges, and jackfruits, which are harvested and served with school lunches (Byaruhanga, 2016; Nonnecke et al., 2016).

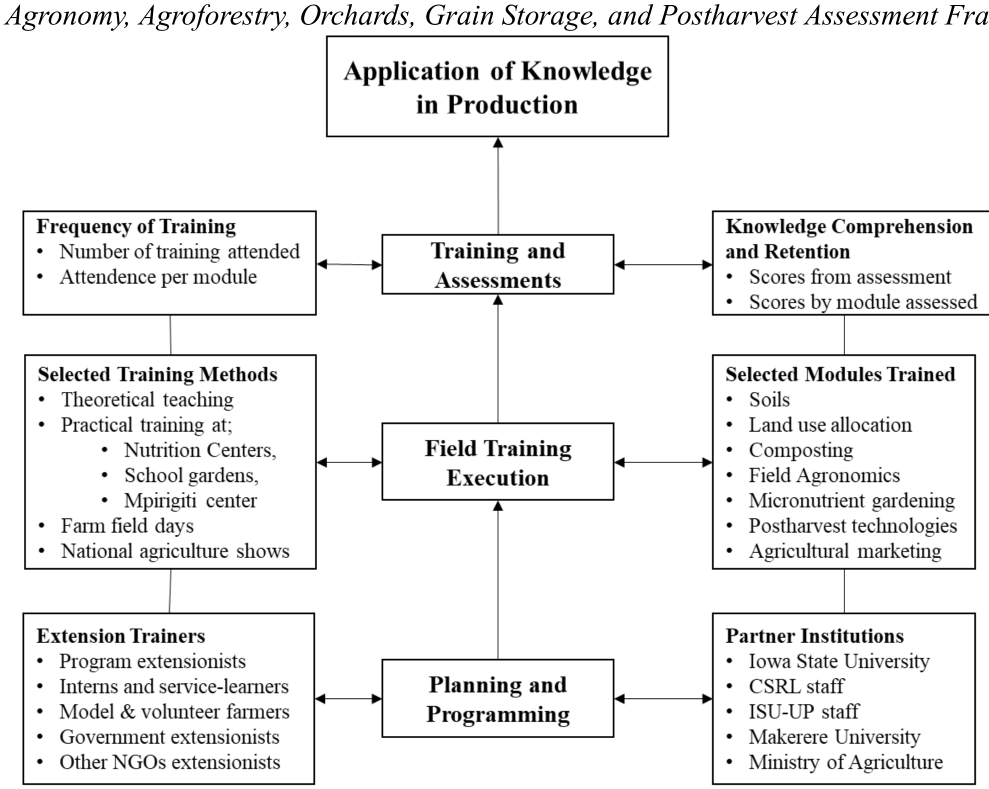
In the *grain storage and postharvest* program, the CSRL/ISU–UP goal is to reduce postharvest losses at schools and communities to enhance food security. The program looks for ways of reducing pest infestation, losses due to spillage, eliminating molding, and extending the shelf life of stored grains (Ahimbisibwe et al., 2024; Asimo et al., 2024; Bbosa et al., 2017; 2020; Brumm et al., 2021; Mayanja et al., 2018; Tumutegyereize et al., 2022). Farmers affiliated with the postharvest program in addition to training, receive hermetic silos and tarpaulins at subsidized prices by the program. Farmers also have access to grain cleaning machines to ensure that grains are clean before they are stored to increase their shelf life and/or sold for a premium price in the future (Mayanja et al., 2018; Tumutegyereize et al., 2022).

Adopting and implementing the practices in the agronomy, agroforestry, orchard, grain storage, and postharvest programs require continuous education, more so in the program operational area with low postsecondary education (Ikendi, Owusu et al., 2023a; Martin, 2018). To promote behavioral changes toward food and nutrition security through adult education, the CSRL restated its mission to include education: "CSRL and ISU–UP use the power of education to develop sustainable communities and responsible global citizens" (Ikendi & Retallick, 2023a, p. 645), operationalized in the capacity development model. These international development efforts align with the Iowa State University mission: "Create, share, and apply knowledge to make Iowa and the world a better place" (ISU, 2016, p. 2). They also align with the American Association for Agricultural Education (AAAE) national research agenda (2016–2020) priority seven of developing programs to tackle complex issues, including food and nutrition insecurity (Andenoro et al., 2016) and research value on international initiatives (AAAE, 2023).

Theoretical and Operational Frameworks

This study was grounded in the theory of planned behavior (Ajzen, 2020), which supposes that when we plan to do something, we do it based on three intentions—behavior attitude, subjective norm, and perceived behavioral control. The *behavior attitude* ascribes to how we think and feel about behavior, which relates to two concepts—affective attitude describing a belief about the attitude—behavior to be enjoyable or not, and instrumental attitude—belief about the attitude—behavior, whether beneficial or harmful. The *subjective norms* relate to the support given significantly by others, e.g., family and friends, and it has two concepts, i.e., the injunctive norms—do others encourage to do the behavior, and the descriptive norms—do others in the group engage in the same behavior or not? *Perceived behavioral control* relates to the feeling capable and confident to do a behavior, which requires one to have the capability and intention to overcome barriers and challenges. The pressures are especially felt given the high levels of food and nutrition insecurity globally (FAO et al., 2023), in Uganda (von Grebmer et al., 2023), and also specific in Kamuli (Ikendi, Owusu et al., 2023a; 2023c) amidst the recurrent rising food prices (Headey & Ruel, 2023). When all three intentions are fulfilled, we feel strong and more likely to engage in a behavior. This theory informs the training operations (Figure 2) of the CSRL/ISU-UP in Kamuli, Uganda.

Figure 2: *Agronomy, Agroforestry, Orchards, Grain Storage, and Postharvest Assessment Framework*



Training programs are organized within communities responding to needs expressed by farmers and schools directly through extension and outreach coordinators, rapid appraisal assessments, and/or based on research findings supported by the program. The training process starts with the planning phase which involves programming and finding resources to empower the educators in conducting the extension education programs. There are two components in the planning phase: the extensionists who conduct the training and the partner institutions. In addition to the program coordinators, university interns, and global service learners work with communities reciprocally through school gardening, farm visits, and related projects (Banige et al., 2024a; 2024b; Ikendi, 2022; Ikendi, Retallick, et al., 2023; Nonnecke et al., 2015). Having model/volunteer farmers as part of educators embraces indigenous knowledge, co-creation of knowledge—motivational aspect to participate in adult learning (Merriam & Baumgartner, 2020; Schunk, 2020), and also an element of community empowerment (Dewey, 1938; Freire, 2018). Farmers as educators are an element that suits aspects of the subjective norm in the theory of planned behavior. They encourage fellow farmers to adopt recommended agricultural practices—injunctive norms and implement good practices as model farmers—descriptive norms (Ajzen, 2020).

The blend of extension educators, including program staff, university service learners, and partners from the government and NGOs, depict the public-private partnership described in the CSRL's tapping philanthropy (Butler & McMillan, 2015). Also, what guides programming are the values of the theory of change, understanding the community customs, and the indigenous knowledge brought by farmers as co-educators (Ikendi & Retallick, 2023b; Masinde & McMillan, 2015) blending with science knowledge from institutions and research supported by the program (Acker et al., 2015; Ikendi & Retallick, 2023a; 2023b). These aspects define the operationalization of the capacity development model of the CSRL/ISU-UP and reinforce the U.S. land-grant ethos in Uganda (Ikendi & Retallick, 2023b).

In the execution of the training program, extension educators blend the modules they use to train based on the needs and the season of the farmers' calendar and the methods of training that best relay the messages to the farmers. The variety of modules trained, including soils, composting, land use planning, micronutrient vegetable gardening, agronomical practices, postharvest, and marketing practices, allows the farmers to choose what to learn that suits their aspirations as they learn from a variety of facilitators and methods. These modules are trained in a sequence from land preparation and mapping through planting and postharvest management of the harvest to increase shelf life and marketability tailored across the seasons. Both the theoretical and practical training is conducted at the Mpirigiti Rural Training Center (Ikendi & Retallick, 2023a, p. 645), nutrition education centers (Ikendi, Owusu et al., 2023b), school gardens–a component of the university global service-learning in schools supported by the program (Banige et al., 2024a; 2024b; Byaruhanga, 2016; Ikendi, 2022; Ikendi, Retallick et al., 2023; Nonnecke et al., 2015), farm field days, and at national agricultural show every July (Banige et al., 2024a; Ikendi, 2022). These interactive learning processes create meaningful learning experiences and improve the grasp of concepts.

During and after training, educators must assess their learners by asking questions and/or practical demos to demonstrate learning. The outcome is the application of lessons through the implementation of recommended soil amendments, crop production, and postharvest management practices. Applying knowledge learned based on indigenous knowledge and scientific research conducted within the local environment is a move towards ensuring high agricultural productivity. The application is accompanied by field monitoring of activities by the extension educators for additional guidance to improve knowledge comprehension and retention through continuous learning engagement (Ikendi, Owusu et al., 2023b). To further instigate behavioral change towards participation in adult education, the President of Iowa State University, in her message embedded in the "2050 time capsule", implored the people of Kamuli district to end hunger but never to stop hungering for knowledge (Ikendi & Retallick, 2023a, p. 649). This message motivates the community to keep attending the training as called on to keep up with the latest technology and innovations in their cropping systems and postharvest management.

Purpose and Objectives of the Study

This study aimed to assess the dimensions of household participation in the CSRL/ISU-UP agronomy, agroforestry, orchards, grain storage, and postharvest extension education programs on farmers' livelihoods in the Kamuli district of Uganda. Specific objectives were to:

1) Assess the rate of household participation in extension education programs,
2) Find out the land access potential between trained and non-trained households,
3) Establish the trends of crop production across seasons between trained and non-trained,
4) Determine the overall crop production potential of small-scale landholder farmers,
5) Identify changes in livelihoods attributed to crops grown among trained and non-trained,
6) Compare household practices associated with postharvest technologies and
7) Identify the challenges faced by trained and non-trained households in crop production.

Methodology

This study was part of a larger cross-sectional survey that assessed the impact of participation in livelihood education programs on household food and nutrition security in Kamuli district, Uganda. This assessment was commensurate with the CSRL/ISU–UP outcome evaluation to assess the impact of the 2014–2019 strategic plan and provide a foundation for the 2020–2024 strategic planning (Ikendi & Retallick, 2023a, p. 647). Data were gathered data from households in the Butansi and Namasagali Sub-counties of Kamuli, where CSRL/ISU–UP works to end global hunger through interrelated livelihoods education programs (see the map of the study area in Ikendi, Owusu et al. 2023a, p. 242). Approval to conduct this study was obtained from the ISU Institutional Review Board under IRB#18-356-01.

Nutrition education centers (NECs) were the basis of purposive sampling—NECs are community-based satellite centers where at-risk-malnutrition reproductive mothers and infants and children of 0-59 months of age are rehabilitated through nutritional therapy of nutrient-dense porridge and related health activities (Ikendi, Owusu et al., 2023b). The NECs served a total of 1,503 clients between 2014–2018, all clients were eligible participants. We established a representative sample of 306 participants at a 95% confidential interval with a 5% margin of error. The list of clients was obtained from the program office in Kamuli. During data collection, the community-based NEC trainers led the team of trained research assistants and the Co-Principal Investigator (Co-PI) to the target households. Only clients above 18 years old and who provided verbal consent were interviewed. The survey tool was written in English, but all questions were asked in "Lusoga," a local dialect—a native language of the Co-PI, most research assistants, and NEC trainers. A total of 219 (70.6%) households who had participated in the agronomy were accessed and interviewed. We intended to compare crop production and management practices between trained and non-trained households, and we interviewed an additional 235 non-trained households within a quarter-mile radius of an interviewed trained household, giving an overall of 454 households in the study.

Data Collection and Analysis

Data were collected and analyzed based on the seven objectives. Objective one focused on determining the frequency of participation in the extension education programs. The first part of objective one established the number of training modules a household member participated in. There were seven modules considered (see Figure 2). The question was a "yes" or "no," asking if a household participated in any specific module. Part two asked for the frequency of participation in the training where participants estimated the number of times they attended every module in part one from 2014 through 2018. We categorized the estimated number of times attended as "1" for responses of less than five times, "2" for 5-10, and "3" for >10 times of participation in a particular module. In analysis, we summed up the categories to generate a minimum of 7 times and a maximum of 21, equating it to modules. Secondly, we generated a three-tier cluster to represent the overall rate of participation where: "1" represents fair (1-7 times), "2" for good (8-14 times), and "3" for very good (15-21 times) participation.

Additionally, in objective one, the study assessed knowledge comprehension and retention after long-term training with a set of six questions that required short responses. The research team developed the questions based on the training in each module, and the questions were then discussed with the program extensionists. The research team and the extensionists agreed on the "relative right answers," which were used as a grade book during data entry. Only one point was earned for each "correct answer" and zero for the "seemingly wrong" answers. A minimum of zero and a maximum of six points were earned. We generated three clusters of points with 0-2 points "below average," 3 points "average," and 4-6 points "above average." We generated frequencies and percentages to measure the central tendency by modules and categories.

Three questions were asked on objective two on land acreage access and use, including how much land this household owns/has, how many acres are under use, and how many acres the household hire/borrow in the season for crop production. In objective three, the study established the crop production trends in three main seasons of March–July 2014, 2017, and 2018 between trained and non-trained households. Fifteen crop and vegetable varieties commonly grown were traced. The year 2014 was used as a baseline when ISU–UP was operationalized as a CSRL partner, 2017 was used as a reference since it was relatively in the middle of the 2014/2019 CSRL/ISU-UP strategic plan that was under impact evaluation, and 2018 was used as the endline as it had the latest crop yield data at the end of the strategic plan (Ikendi & Retallick, 2023a). The study traced whether households produced the same 15 crops in all seasons. We hoped that with the continued extension education, there would be stimulation of production and continuity, including non-program affiliates, because of social capital, which could involve sharing knowledge and even seeds as a community (Malual & Mazur, 2020; Sseguya et al., 2018).

Objectives four and five investigated the changes in the household livelihoods attached to producing a specific crop, emphasizing three livelihood indicators, including income, food supply, and area cultivated, using 2017 as a reference. Income was calculated as the percentage of output sold, the percentage of households sold, and total sales income in Uganda shillings converted to U.S. dollars (1 USD: 3,400UGX, CSRL FY 2018/19). Food supplies were a function of total output minus total sold to get the household food reserves. Land area cultivated was a function of the total area cultivated per crop. We generated percentages from the results on every crop for each indicator, which is vital in planning training programs and seed aid supplies to match the community's demand and desire for a crop. Objective six assesses indicators of grain storage and postharvest practices between trained and non-trained, and objective seven sought challenges faced by a) farmers who cultivated and b) those who never cultivated in 2017.

Results

A total of 454 households participated in this study, among whom 48.2% (*n*=219) participated in the extension education programs on agronomy, agroforestry, orchards, grain storage, and postharvest practices organized by the CSRL/ISU–UP in the Kamuli district of Uganda for the period 2014–2018 of this study. Up to 58.5% of the 219 households trained in all seven modules considered in this study (Table 1). Most households (80.4%) trained for at least five modules, and 55.7% attended between 1-7 of the 21 expected rounds of training for the period 2014–2018, which is considered low participation. By module, participation was highest in micronutrient vegetable gardening (94.1%) and least (74.4%) in gross margin analysis and marketing of crop produce. The average score in knowledge assessment was 84.9%, and most farmers (95.0%) responded well to grain amaranths questions. Households are expected to implement the learned lessons. A snapshot of the micronutrient vegetable gardening promoted through sack gardens, keyhole gardens, and kitchen gardens indicates that most trainees (55.3%) had at least one of these gardens around their compounds compared to the 11.9% who possessed them but never trained. Although the overall number of households with these gardens was low, i.e., 122 kitchens, 24 sack, and 19 keyhole gardens, the majority, i.e., 100, 22, and 15 respectively, were for trainees.

Table 1

Household Participation in Agronomy, Agroforestry, Orchards, Grain Storage, and Postharvest Training

Variable	Indicator and Measure (*n*=219)	*f*	%
Agronomy and postharvest modules trained	Soil types and soil improvements	187	85.4
	Manure composting	182	83.1
	Land use mapping and planning	163	74.4
	Field agronomical practices	197	90.0
	Micronutrient vegetable gardening	206	94.1
	Grain storage and postharvest technologies	187	85.4
	Marketing and gross margin analysis of crop products	163	74.4
Number of modules trained	Above average (i.e., 5-7 modules)	176	80.4
	Average (i.e., 3-4 modules)	25	11.4
	Below average (i.e., 1-2 modules)	18	8.2
Number of times attended training	Very good attendance (i.e., 15-21 training rounds)	14	6.4
	Good attendance (i.e., 8-14 training rounds)	83	37.9
	Fair attendance (i.e., 1-7 training rounds)	122	55.7
Questions and number of relatively correct responses	How do you tell that amaranths are ready to harvest?	208	95.0
	How do you dry your crops to ensure quality output?	206	94.1
	Why do you rotate crops on your farm each season?	198	90.4
	When do you prepare land for next season?	189	86.3
	How do you make compost manure?	175	79.9
	What is the spacing for grain amaranths?	140	63.9
Average scores from knowledge assessment	Above average (i.e., 4-6 points)	205	93.6
	Average (i.e., 3 points)	08	03.7
	Below average (i.e., 0-2 points)	06	2.7

Land Accessibility and Use

Of the 454 households surveyed, 95.4% *owned land* with an average size of 3.54 acres (1.43 ha). Households who *used their land* for crop production were 99.1% with an average farm size of 2.46 acres (1.00 ha). Households who accessed land through *hiring/borrowing* were 32.4% with an average of 1.52 acres (0.62 ha). As depicted in Tabel 2, there were no significant differences among trained and non–trained households across the three land access and use categories.

Table 2

Land Access and Use for Crop Production in Season 1 of 2017 among Farmers in Kamuli, Uganda

Land Indicator/Acres	Households	*n*	Mean	*SD*	Min.	Max.	*p*-value
How much land does this household own/have?	Not Trained	219	2.72	0.266	0.2	40.0	0.235
	Trained	214	4.38	0.452	0.3	300.0	
	Total	433	3.54	4.571	0.2	300.0	
How many acres are under use?	Not Trained	217	2.26	2.014	0.1	15.0	0.063
	Trained	213	2.66	2.470	0.3	20.0	
	Total	430	2.46	2.258	0.1	20.0	

How many acres did you hire/borrow this season	Not Trained	78	1.55	1.301	0.3	8.0	
	Trained	69	1.50	1.198	0.3	7.0	0.813
	Total	147	1.52	1.250	0.3	8.0	

Crop Production Trends

The study identified a general increase in trained households cultivating grain amaranth, soybean, common beans, high iron beans, and groundnuts between 2014, 2017, and 2018. Non-trained households were more likely to grow those crops before 2014 than the trained. Households growing cereals like millet, maize, and rice reduced between 2014 and 2017 but increased in 2018. Staple food crops like sweet potatoes and cassava had the highest number of households in production throughout the seasons. However, they depict a low production in 2017, although trained households were likely to engage more in their production. Vegetables like cowpeas, collards, spring onions, and eggplants had the lowest number of households in production in all seasons.

Table 3

Household Engagement in Crop Production in the Main Seasons of March-July of 2014, 2017, and 2018

Major Crops	Main Seasons	Non-trained	Trained	Total	*p*-value
Grain Amaranths	2014 (*n*=72)	59.3	38.4	41.6	0.036*
	2017 (*n*=173)	11.5	66.7	38.1	<0.001*
	2018 (*n*=160)	92.6	92.5	92.5	0.670
Soybeans	2014 (*n*=166)	90.2	57.5	68.6	0.001*
	2017 (*n*=242)	34.9	73.1	53.3	0.001*
	2018 (*n*=226)	92.7	93.8	93.4	0.473
Millet	2014 (*n*=87)	50.8	65.1	59.2	0.059
	2017 (*n*=115)	14.5	37.0	25.3	0.001*
	2018 (*n*=103)	88.2	90.1	89.6	0.498
Maize (Corn)	2014 (*n*=370)	96.7	98.0	97.4	0.337
	2017 (*n*=380)	78.3	89.5	83.7	0.001*
	2018 (*n*=362)	94.6	95.9	95.3	0.352
Common Beans	2014 (*n*=261)	95.3	88.1	91.3	0.024*
	2017 (*n*=274)	52.3	68.9	60.4	0.001*
	2018 (*n*=257)	91.9	95.4	93.8	0.173
Sweet Potatoes	2014 (*n*=244)	98.3	91.4	94.6	0.012*
	2017 (*n*=250)	50.2	60.3	55.1	0.020*
	2018 (*n*=243)	97.5	98.5	98.0	0.454
Cassava	2014 (*n*=168)	82.3	87.3	84.8	0.219
	2017 (*n*=171)	34.5	41.1	37.7	0.087
	2018 (*n*=165)	96.3	96.7	96.5	0.608
Groundnuts (Peanuts)	2014 (*n*=118)	78.2	80.3	79.2	0.755
	2017 (*n*=121)	26.4	26.9	26.7	0.893
	2018 (*n*=108)	85.5	93.2	89.3	0.170
High Iron Beans	2014 (*n*=10)	33.3	22.0	22.7	0.650
	2017 (*n*=44)	1.3	18.7	9.7	<0.001*
	2018 (*n*=37)	66.7	85.4	84.1	0.393
Cowpeas	2014 (*n*=11)	6.3	30.0	17.7	0.014*
	2017 (*n*=24)	2.1	8.7	5.3	0.002*
	2018 (*n*=22)	100	89.5	91.7	0.449

Collards (Kale)	2014 (*n*=7)	12.9	10.7	11.9	0.795
	2017 (*n*=16)	1.7	5.5	3.5	0.029*
	2018 (*n*=15)	75	100	93.8	0.074
Spring Onions	2014 (*n*=7)	6.9	14.7	11.1	0.326
	2017 (*n*=27)	1.3	11.0	5.9	<0.001*
	2018 (*n*=23)	100	83.3	85.2	0.444
Eggplants	2014 (*n*=83)	57.1	62.2	60.1	0.552
	2017 (*n*=103)	14.0	32.0	22.7	<0.001*
	2018 (*n*=95)	93.9	91.4	92.2	0.657
Pawpaw	2014 (*n*=36)	36.8	56.4	46.8	0.085
	2017 (*n*=38)	6.4	10.5	8.4	0.113
	2018 (*n*=34)	93.3	87.0	89.5	0.531
Rice	2014 (*n*=43)	93.8	87.5	89.6	0.504
	2017 (*n*=45)	6.4	13.7	9.9	0.009*
	2018 (*n*=41)	80.0	96.7	91.1	0.064

*Indicates significant associations with the production of a crop in a season between households.

Household Livelihoods Changes Attributed to Specific Crop Grown in Season-1 of 2017

In season 1, 2017, 396 (87.2%) households engaged in production from whom the study assessed their livelihood changes on indicators of area cultivated, food supply, and income. The findings indicated that most of the changes were attributed to food supplies based on the high proportion of reserves rather than sales (Table 4). In food supply, the total yield and proportion of reserves were used as indices. Food reserves were in two categories, i.e., food in the garden, like sweet potatoes and cassava, and food in-store, especially grains. Regarding area cultivated, it was established that traditional staple food crops, including maize, sweet potatoes, beans, and cassava, had at least half an acre of land area cultivated on average. In the revenue index, crops like maize, rice, amaranths, soybeans, millet, beans, and cassava had a higher proportion of sales revenue. To promote food production, the program provides seeds to farmers, mostly at-risk for malnutrition mothers, and the equivalent weight of seeds given is returned. Mostly, farmers received seeds of soybeans, amaranths, high-iron beans, common beans, and millet. Returned seeds were higher for amaranths, millet, common beans, and high iron beans by the survey time.

Table 4

Estimations of Crop Production and Sales During the Reference Season–1 of 2017

Selected Food Crops Grown in Season 1 of March-July, 2017	Total Acres Planted	Program Seeds (Pounds)	Total Yield (Pounds)	Seeds Returned (Pounds)	Percent Yield Sold	Percent of HH Sold	Total Revenue (Dollar)
Amaranths (*n*=173)	49.0	147	6,517	476	41	35.3	713
Soybeans (*n*=242)	94.6	473	20,225	235	36	28.9	1,272
Iron Beans (*n*=44)	15.9	123	1,846	143	5	18.2	17
Millet (*n*=115)	41.2	50	15,969	118	42	13.9	1,028
Cowpeas (*n*=24)	1.4	26	114	9	-	-	-
Collards (*n*=15)	1.3	n/a	545	-	33	46.7	4
Onions (*n*=27)	0.3	n/a	247	-	-	-	-
Eggplants (*n*=103)	-	n/a	12,268	-	7	26.2	150
Pawpaw (*n*=28)	-	n/a	8,145	-	3	25.0	9
Maize (*n*=380)	442.4	-	433,190	-	39	46.6	10,643

Cassava (*n*=171)	85.7	n/a	126,898	-	5	8.1	414
Groundnut (*n*=121)	51.9	-	16,793	-	20	15.7	548
Beans (*n*=274)	128.5	59	34,775	253	11	16.4	1,496
S. Potatoes (*n*=250)	117	n/a	177,491	-	4	5.6	302
Rice (*n*=45)	33.1	-	58,179	-	41	46.7	4,356

HH=Households; Exchange rate: 1US$=3,400 UGX, adopted from CSRL/ISU–UP 2018/19 FY.

When farmers were directly asked about their perception of livelihood changes, over 70% believed their food supply changed because of their engagement in the production of 12 of the 15 crops (Table 5). The perception of changes in income was related to the production of maize, rice, amaranth, and soybean within a range of 30–50%. Changes in land acreages planted were the least, mostly less than 20%, linked to the cultivation of amaranths, soybeans, and maize.

Table 5

Perception of Livelihoods Changes Attributed to Production of the 15 Selected Crops

Major Crops	Livelihood Indicator	Non-trained	Trained	Total	*p*-value
Grain Amaranths (*n*=173)	Income	18.5	34.9	32.4	0.094
	Food Supply	81.5	86.3	85.5	0.513
	Area Planted	22.2	19.2	19.7	0.715
Soybeans (*n*=241)	Income	34.1	28.9	30.7	0.406
	Food Supply	85.4	86.2	85.9	0.866
	Area Planted	19.5	10.7	13.7	0.059
Millet (*n*=115)	Income	17.6	8.6	11.3	0.164
	Food Supply	76.5	79.0	78.3	0.763
	Area Planted	14.7	7.4	9.6	0.225
Maize (*n*=378)	Income	46.2	48.5	47.4	0.660
	Food Supply	86.3	82.5	84.4	0.302
	Area Planted	11.5	10.3	10.9	0.716
Common Beans (*n*=274)	Income	17.9	14.6	16.1	0.457
	Food Supply	74.8	80.8	78.1	0.232
	Area Planted	9.8	7.9	8.8	0.598
Sweet Potatoes (*n*=250)	Income	5.9	5.3	5.6	0.829
	Food Supply	67.8	72.7	70.4	0.394
	Area Planted	4.2	6.1	5.2	0.517
Cassava (*n*=171)	Income	4.9	11.1	8.2	0.142
	Food Supply	72.8	71.1	71.9	0.802
	Area Planted	4.9	4.4	4.7	0.879
Groundnuts (*n*=121)	Income	14.5	16.9	15.7	0.713
	Food Supply	72.1	71.2	71.7	0.909
	Area Planted	1.6	3.4	2.5	0.530
High Iron Beans (*n*=44)	Income	-	9.8	9.1	0.570
	Food Supply	100	80.5	81.8	0.398
	Area Planted	-	22.0	20.5	0.363
Cowpeas (*n*=24)	Income	-	-	-	-
	Food Supply	60.0	84.2	79.2	0.236
	Area Planted	40.0	10.5	16.7	0.116
Collards (*n*=14)	Income	33.3	18.2	21.4	0.571

	Food Supply	100	72.7	78.6	0.308
	Area Planted	-	-	-	-
Spring Onions (*n*=27)	Income	-	-	-	-
	Food Supply	100	54.2	59.3	0.128
	Area Planted	-	-	-	-
Eggplants (*n*=103)	Income	9.1	12.9	11.7	0.578
	Food Supply	78.8	70.0	72.8	0.350
	Area Planted	6.1	1.4	2.9	0.342
Pawpaw (*n*=38)	Income	-	4.3	2.6	0.413
	Food Supply	46.7	56.5	52.6	0.552
	Area Planted	-	-	-	-
Rice (*n*=45)	Income	53.3	43.3	46.7	0.526
	Food Supply	73.3	63.3	66.7	0.502
	Area Planted	13.3	6.7	8.9	0.459

Challenges Faced by Farmers in Crop Production

In this study, 392 (99.0%) households among the 396 who cultivated in season 1 of 2017 reported challenges (Table 6), mainly soil infertility (54.7%) and striga weed (54.1%). Trained households (42.3%) were significantly associated with challenges of water scarcity than 30.2% of non-trained households. Relatedly, 52 (89.7%) households among the 58 who *never* cultivated in season-1 of 2017 reported challenges, mainly lack of access to land (35.2%) and sickness (31.5%). Significantly, 15.4% of the trained households were more likely to face challenges associated with pregnancy that impended their participation in crop production in 2017.

Table 6

Challenges Faced by Small-scale Farmers by Participation in Crop Production in Kamuli, Uganda

Households	Major Challenges	Non-trained (*n*=189)	Trained (*n*=203)	Total (*n*=392)	*p*-value
Households who grew food crops in season one of 2017	Soil infertility	57.4	52.2	54.7	0.299
	Striga weed	56.1	52.2	54.1	0.443
	Field Pests	47.9	43.3	45.5	0.370
	Water scarcity	30.2	42.3	38.0	0.002
	Limited land	28.7	26.6	27.6	0.513
	Theft of Crops	16.5	18.7	17.6	0.563
	Limited market	19.1	16.3	17.6	0.453
	Crop Diseases	8.5	9.4	9.0	0.769
Households	Major Challenges	Non-trained (*n*=41)	Trained (*n*=13)	Total (*n*=54)	*p*-value
Households who did not grow food crops in season one of 2017	Lack of access to land	34.1	38.5	35.2	0.776
	Sickness	26.8	46.2	31.5	0.191
	Inadequate seeds	26.8	7.7	22.2	0.148
	Pregnancy issues	2.4	15.4	5.6	0.076
	Not at home	4.9	7.7	5.6	0.700
	Infertile land	4.9	-	3.7	0.417
	Poor weather	4.9	-	3.7	0.417
	Prohibited by husband	2.4	-	1.9	0.570

Grain Storage and Postharvest Handling Technologies

Postharvest technologies are very significant in crop production to help farmers tell when crops are ready for harvest, how to harvest, dry, and keep them either for home consumption or sale. The survey focused mainly on grain crops, and the majority (63.0%) shelled by beating using wooden sticks. However, trained households were 16.0% more likely to shell using machines (see Table 7 for details). During drying, most farmers (71.1%) dry on bare ground, but trained households were 37.9% more likely to dry on tarpaulins. To check moisture content to determine grain dryness, all households (100%) reported using their teeth to bite the grains, 36.6% snapped with their hand, and none used a moisture meter. Relatedly, 444 (97.8%) reported having kept part of their harvest for future use with the majority (91.4%) keeping in bags/sacks.

Table 7

Grain Storage and Postharvest Practices By Small-scale Farmers in Kamuli, Uganda

Indicators of Postharvest	Postharvest Practices	Not Trained (*n*=235)	Trained (*n*=219)	Total (*n*=454)	*p*-value
How do you shell your crops?	Beating with sticks	63.4	62.6	63.0	0.852
	Using hands	36.6	29.2	33.0	0.095
	Machine-sheller type	7.2	16.0	11.5	0.003*
During drying grains, what do you dry your grain on?	Tarpaulin	15.3	37.9	26.2	<0.001*
	Bare ground	83.0	58.4	71.1	<0.001*
	Concrete floor	0.9	0.5	0.7	0.604
	Cloth	-	6.4	3.1	<0.001*
	Mats	0.4	-	0.2	0.334
	Iron sheets	0.4	-	0.2	0.334
How do you check the moisture?	Bite with teeth	100	100	100	-
	Snap with fingers	35.7	37.4	36.6	0.707
	Moisture meter	-	-	-	-
Storage of harvests		Not Trained (*n*=226)	Trained (*n*=218)	Total (*n*=444)	*p*-value
Where do you store your grains after harvest	Bags	92.0	90.8	91.4	0.649
	Metallic silos	1.8	1.4	1.6	0.739
	Plastic silos	1.3	0.9	1.1	0.682
	Pots	0.9	0.5	0.7	0.584
	Jerrycans	14.2	12.8	13.5	0.685

*Indicates statistical associations of grain storage and postharvest practices between households.

Discussions and Conclusions

Participation in agronomy, agroforestry, orchards, grain storage, and postharvest extension education programs overall was high—above 70%, reflecting a high enthusiasm to learn. This enthusiasm gives hope given the fact that the population of Uganda is youthful, more so in the Kamuli district (UBOS, 2017) and study area which has low formal education (Ikendi, Owusu et al., 2023a; Martin, 2018). The CSRL/ISU–UP LEPs build the competencies of households that support making informed decisions in managing their enterprises with the education aspect vested in its mission statement (Ikendi & Retallick, 2023a). Moreover, the program was intentional in executing its training programs by blending model farmers and volunteers as trainers and community-based NEC trainers in post-training garden monitoring with program extensionists (see Figure 2). This approach of training prioritizes indigenous knowledge of farmers which grows with experiences of interacting with their environment, and this knowledge influences their participation in training; and implementation of innovations and participation their assessments (Ikendi & Retallick, 2023b; Kasule, Waaswa et al., 2020a; Masambuka-Kanchewa et al., 2022; Masinde & McMillan, 2015; Pound & Conroy, 2017; Rogers, 2003; Wanyakha, 2016).

Engaging farmers as trainers also leads to the co-creation of knowledge, a motivational aspect for adult learners to participate in education programs (Merriam & Baumgartner, 2020; Schunk, 2020), which philosophically doubles as an element of community empowerment through collaborative problem-solving (Dewey, 1938; Freire, 2018). Engaging academics like university educators and university service learners harness expert knowledge, bridge the gap between institutions and the communities that implement their innovations, and promote reciprocity of learning (Ikendi, Retallick, et al., 2023). The element of involving government agencies like MAAIF and other NGOs is a drive to the foundational promise of the program toward a public–private partnerships for rural development (Butler & McMillan, 2015).

Similarly, having farmers and NEC trainers as co-trainers suits the different norms of the theory of planned behavior norms (Ajzen, 2020). The subjective norms, for example, speak about the support given by members in our social circles who are in this study, fellow farmers, and extensionists who are fellow community members. The subjective norm further drives into two concepts of injunctive norms—do others encourage you to do the behavior? and the descriptive norms—do others in the group engage in the same behavior or not? Most of the NEC trainers were former enrollees at the at-risk-for-malnutrition rehabilitation centers who took leadership positions as trainers after rehabilitation (Ikendi, Owusu, et al., 2023b). NEC trainers have been empowered by the program and are influential in their communities, encouraging mothers to participate in various livelihood education programs, including agronomy to adopt the related practices with their full support through routine garden monitoring (Ikendi & Retallick, 2023a).

Why and Where is the Learning in the Different Modules?

Soil types and soil improvements: Soil types have a profound impact on both soil quality—indices of acidity or alkalinity and cation exchange capacity, and soil fertility—indices of phosphorus, calcium, and base saturation, making it an essential aspect of continuous education for farmers and planning the need for soil improvements (Akitwine, 2021; Anderson, 2023; Apanovich & Lenssen, 2018; Kabango et al., 2022; Kollie et al., 2023; Kyebogola et al., 2020). Farmers in the Kamuli district perceived soil health as a great indicator of crop growth and yield index (Lege, 2020). However, there is still a challenge of low yield; for instance, 213.8 pounds (97.2 kilograms) per acre was estimated in soybeans (see Table 4). Nevertheless, research institutions like Makerere University Centre for Soybean Improvement and Development (MAKCSID) picked interest in capacity building among farmers to improve the production, consumption, and marketing of soybeans in many districts in Uganda, including Kamuli (Tukamuhabwa et al., 2019). This collaboration is essential in helping to design extension education materials for extension adoption.

Manure composting: Farmers need proper education on how to improve soil productivity using ecologically sustainable methods like manure, enriching both soil volume and crop with nutrients (Edwards & Araya, 2011; Kabango et al., 2022; Kyebogola et al., 2021; Wokibula & Westgate, 2016). The need to reconnect to the ecological community is vital (Ikendi, 2023; Montgomery, 2021; Thompson, 2017). Soil manipulation using fertilizers can work but is not sustainable with low incomes from sales (see Table 4). Studies in beans, for instance, have indicated that soil condition and bean genotype determine the number of bean pods–a yield index (Bulyaba et al., 2020; Goettsch et al., 2016; Okii et al., 2019). However, experiments conducted in Central Uganda indicated that applying fertilizers did not increase bean yields of NABE4 (Goettsch et al., 2016), and adding lime did not increase yields of newly released bean varieties (Bulyaba et al., 2020). In the same region, no variations were found in soil quality and fertility using fertilizers (Apanovich & Lenssen, 2018). Nevertheless, there is a consistent, rapid decline in fertility rates (Kollie et al., 2023), reinforcing the need for continuous education on soils and ecological practices.

Micronutrient vegetable gardening: The use of sack gardens, keyhole gardens, and kitchen gardens for micronutrient vegetable growing are land-sparing production techniques, especially in Kamuli, where land acreage is limited (see Table 2). These gardens provide households with vegetables, reducing the cost of buying from the market, and the surplus can be sold off to raise income for other household needs. Although we found that trained households were likely to possess these gardens, the study generally found very low numbers of these gardens. These findings match the earlier results of Masinde and McMillan (2015), who concluded that seven years after the introduction of kitchen and sack gardens in the program, farmers had abandoned the technology. The reduction in the adoption of such technology speaks to the need for continued extension education and monitoring of the implementation of vegetable gardening.

In other analyses within this sample, households with micronutrient gardens were likely to be food secure (Ikendi, Owusu, et al., 2023a), with good diets (Ikendi, Owusu, et al., 2024), and were less likely to have malnourished children (Ikendi, Owusu, et al., 2023c). Sack gardening is promoted in schools as a component of the school garden and service-learning, supporting knowledge transfers to homes through home gardens as a source of food and income (Duerfeldt et al., 2016; Banige et al., 2024a; 2024b; Ikendi, 2022). In Lesotho, keyholes are a food security strategy (Muroyiwa & Ts'elisang, 2021); keyhole gardens are an adaptation strategy to climate mitigation for their capacity to hold water for an extended period during the dry season (Fadairo et al., 2019; Kheleli et al., 2021). Also, they are used to grow crops utilizing recycled urban domestic waste in regenerating natural systems (Mohan et al., 2020). Similarly, vertical sack gardens have been adopted as a way of greening the world (Akinsemolu, 2020). In urban areas, sack gardens are used to grow vegetables, like in Kibera slums in Kenya, improving livelihoods (Gallaher et al., 2015).

Grain storage and postharvest practices: Stressing the significance of recommended postharvest practices is important, especially when the studies are conducted in the same communities, and results are relayed back through extension engagement. Although trained households reported a 37.9% likelihood of drying their harvest on tarpaulins to keep the quality of harvest from contamination with rubbish, dust, and stones and improve their shelf life, in general, most households (71.1%) reported drying on the bare ground. This high percentage is probably related to the high unit cost of the tarpaulins compared to the total yield and overall income from sales (see Table 4). Tibagonzeka et al. (2018) found a higher proportion of up to 93.2% of households drying their harvest on the bare ground within the Kyoga region, where the Kamuli is part, increasing losses, higher aflatoxins and molds (Ahimbisibwe et al., 2024; Akumu et al., 2020).

These findings, together with our findings, make a good call for continuous education on postharvest technologies (Ahimbisibwe et al., 2024; Taku-Forchu, Qu et al., 2023) and similarly guide the planning of postharvest extension materials in conjunction with other studies that provide solutions to identified problems. Bbosa et al. (2017), Brumm et al. (2021), Sserunjogi et al. (2021), and Taku-Forchu, Lambert et al. (2023) recommended adoption of hermetic silos to control the maize weevil. These calls are important because of the low proportion of households in this study (where <2% were found) using hermetic silos. Similarly, mixing grain amaranths and maize cobs was effective in controlling weevils (Bbosa et al., 2020). Also, it supports farmers in accessing locally tailored grain cleaners to improve the quality of stored grains (Mayanja et al., 2018; Tumutegyereize et al., 2022) and grain dryers (Asimo et al., 2024).

Crop Production Trends, Changes in Livelihoods, and Challenges

The study established a general increase in the number of trained households who cultivated both grain amaranth and soybean between 2014–2018. We can infer that a general increase in the production of amaranths was partly a result of the program's operations in promoting these crops to manage malnutrition through the NECs (Ikendi, Owusu et al., 2023b; 2023c). The program relies on scientific research findings

(Acker et al., 2015; Ikendi & Retallick, 2023a) blended with indigenous knowledge (Ikendi & Retallick, 2023b; Masinde & McMillan, 2015) to influence the community to adopt innovations. Grain amaranths, for instance, were introduced in 2005 after understanding that the community was already growing the traditional type of amaranths and that the exotic type would readily be accepted to increase protein uptake (Masinde & McMillan, 2015). Similarly, studies were conducted to assess its nutritional composition (Muyonga et al., 2011) and its economic viability, whose results supported the innovation diffusion especially on the small land acreages of farmers in Kamuli (Ainebyona et al., 2012).

Several other studies have been conducted supported by the program directly or indirectly by the associate directors. These include tomato production (Taku-Forchu, 2019; Tusiime, 2019; Tusiime et al., 2020); tropical pumpkins (Kwikiiriza, 2022); sweat potatoes (Waaswa et al., 2021a; 2021b; Waaswa et al., 2021). These assessments align with what Pound and Conroy (2017, p. 371) advocate, that innovation be driven by research "cognizant of, and responsive to, the context in which rural families are working." Relatedly, the CSRL/ISU–UP partnership with Makerere University resulted in adopting the soybean (Maksoy 3N and 6N) bred by MAKCSID for farmers to grow for its high yields and economic returns (Tukamuhabwa et al., 2019). The study found that soybeans (see Table 4) had the highest amount of planting seeds supplied to farmers by the CSRL/ISU–UP.

For cereals like millet and maize, the trend shows that households engaged in production reduced between 2014 and 2017 but increased in 2018. These cereals are essential in nutrition programs as the main components of therapeutic porridge at rehabilitation centers to manage malnutrition (Ikendi, Owusu et al., 2023b; 2023c). In addition to beans, maize is the main component of "Nyoyo–a mixture of beans and maize cooked together," a school lunch meal served to pupils in elementary schools supported by the program (Byaruhanga, 2016; Nonnecke et al., 2016). However, a reduction in cereal production in 2014–2017 could partially have been hampered by the infestation of Striga–the second most significant challenge to farmers (see Table 7). This parasitic weed is capable of whipping out the whole cereal crop fields (Bisikwa et al., 2022; Hamba et al., 2024; Kasule, Kakeeto, et al., 2023), which earlier caused an alarm in the CSRL program "… we need to figure out how to control Striga or the gains we've made over the last decade will be wasted" (CSRL, 2015, p. 12). Striga thrives where there is soil infertility–the most significant challenge identified by farmers (see Table 7), and also affirmed by the recent studies in soils in the same area (Akitwine, 2021; Anderson, 2023); calling for continued education of households on soils and soil improvements to improve their productivity.

Traditional staple root crops of sweet potatoes and cassava had the highest number of households in production throughout the seasons. However, they depict a very low production in 2017, although trained households were likely to engage more in their production. These crops are essential for food and nutrition security in Kamuli (Ikendi, Owusu et al., 2023a; 2023c; 2024; Seguya et al., 2018). Probably limited land–low acreage cultivated can be attributed to land shrinkage in Kamuli over the years from 4.94 acres as average owned in 2004 to 3.54 acres estimated in 2018, yet, of the 3.54 acres, only 2.45 acres were estimated to be in use on the number of crops. Also, seasonality and rotation could be one of the primary reasons for low production in 2017 but increased in 2018, especially cassava. However, there could be problems with diseases, especially in cassava, specifically mosaic and brown streak diseases, impacting farmers in eastern Uganda, where Kamuli is part (Kasule, Waaswa, et al., 2020a; 2020b). Significantly, Kasule and colleagues, with support from their research institutions, have invested in cassava seed multiplication experiments and capacity building. The success of their endeavors was vested in blending their expert knowledge with indigenous knowledge–involving farmers in experiments and capacity building through lectures and field visits–a precursor to the adoption of innovative ideas in controlling cassava infections.

The total yield and proportion of reserves were used as indices in food supply. Food reserves were in two categories–food in the garden, like sweet potatoes and cassava, and food in-store, especially grains. Local food security crops like potatoes, beans, cassava, and maize had a higher proportion of food reserves than nutrition security crops like amaranths, soybeans, and millet. It is common practice for rural farmers to sell off their produce after harvest. However, farmers who reserve food are more likely to be both food and nutritionally secure. These reserves can be eaten in periods of scarcity and/or sold when prices stabilize. Guided by scientific research, the introduction of hermetic grain silos in the program was a result of their efficiency in controlling weevils in stored grains (Bbosa et al., 2017). Similarly, to maintain the quality of stored grains, a program service learner invented and fabricated a pedal-operated grain cleaner, which has been adopted by the program for farmers and schools (Mayanja et al., 2018).

Implications and Recommendations

Stressing the aspects of strategic capacity building of farmers is vital to support making informed production decisions on different aspects of their farming operations. Providing knowledge through extension education improves production when knowledge is put into practice, ensuring household food and nutrition security, improved income, and asset acquisition after the sale of produce, improving the overall livelihoods as evidenced in this study and several other studies in Uganda (e.g., Asasira et al., 2019; Jjagwe et al., 2022; Kasule, Waaswa et al., 2020a; 2020b). In all extension education efforts, the emphasis is knowledge transfer. In this study, households who went through agronomy and postharvest education were likely to apply the learned techniques, which improved their food and nutrition security (Ikendi, Owusu, et al., 2023a; 2023c; 2024) despite the small-scale application observed in this study.

Extension education programs help to close that information gap between research institutions and the community through the scholarship of engagement with the community. Vested within the U.S. land-grant values of teaching/learning, research/discovery, and engagement/extension (Ikendi & Retallick, 2023b) and with educational aspect lined within its mission statement, the CSRL/ISU–UP capitalizes on scientific research conducted within the local communities blended with indigenous knowledge to create innovative ideas. This approach influences participation in training and adoption of the technologies and eases outcomes assessment. Educators are part of the community in various ways as model farmers, government extensionists, other collaborating NGOs, and university academics, including global service learners reciprocally working with the community through research and implementation of ideas. This significant support given by members of the farmers' social circles is pitched in the theory of planned behavior (Ajaz, 2020), influencing farmers' perception of what is embedded in the extension education packages (Rogers, 2003). These aspects motivate participation in learning delivered through lectures, field days, and national agriculture tours, and engaging schools through school gardens improve the pupils' lifelong learning of agrifood systems. This knowledge trickles down to households when students practice the concepts in home gardening.

To further sustain the achievements, the focus must be on improving process monitoring and outcome evaluation of implementing the learned lessons and practices. Using the CSRL/ISU–UP as a hub of learning the principles of agronomy and postharvest management is a model of knowledge transfer and empowerment, a move towards sustainability. The agronomical and postharvest skills offered by the program form a stock of knowledge available to every community member regardless of their affiliation with the program. Achieving zero hunger by 2030, as stipulated in the sustainable development goals (United Nations, 2016) and the vision for an African renaissance (African Union, 2015), requires a concerted effort from the private and government sectors. The Iowa State University (ISU, 2016), through the CSRL and the AAAE (2023) agenda, is committed to bettering the lives of international communities in their mission and research values, respectively. The ISU president commended the people of Kamuli in the 2050 time capsule to end hunger but never to stop hunger for knowledge (Ikendi & Retallick, 2023a, p. 649). Similarly, the continual translation of the Uganda Food and Nutrition Strategy into reality requires leveraging the capacity of all stakeholders to improve the structural functionality of food and nutrition interventions with the full support of government organs (Office of the Prime Minister, 2020), aligning with the CSRL model of public-private partnership (Butler & McMillan, 2015).

References

Acker, D. G., Musoke, H. K., & Sseguya, H. (2015). Capitalizing on impacts and CSRL's multiplier effects. In M. L. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 223–254). Kumarian Press.

African Union (AU). (2015). *Agenda 2063: The Africa we want.* Addis Ababa, Ethiopia. Accessed at: https://au.int/sites/default/files/documents/36204-doc-agenda2063_popular_version_en.pdf

Ahimbisibwe, S., Ikendi, S., Buyinza, T., Namata, M., Waaswa, A., & Kaaya, A. N. (2024, February 3–6). *Mitigating maize postharvest losses through participatory training in rural Uganda* (Poster presentation). Southern Region of the AAAE Conference. Atlanta, Georgia, United States. https://www.researchgate.net/publication/377965311

Ainebyona, R., Mugisha, J., Kwikiriza, N., Nakimbugwe, D., Masinde, D., & Nyankanga, R. O. (2012). Economic evaluation of grain amaranth production in Kamuli district, Uganda. *Journal of Agricultural Science and Technology A*, *2*(2A), 178−190. https://www.researchgate.net/publication/319680122

Ajzen, I. (2020). The theory of planned behavior: Frequently asked questions. *Human Behavior and Emerging Technologies*, *2*(4), 314–324. https://doi.org/10.1002/hbe2.195

Akinsemolu, A. A. (2020). *The principles of green and sustainability science*. Springer.

Akitwine, F. (2021). *Pedology of typical soils of Kamuli District and pedotransfer functions to predict cation exchange capacity in limited-resource settings* [Master's thesis, Iowa State University]. Theses and Dissert. https://dr.lib.iastate.edu/handle/20.500.12876/jw27mp4v

Akumu, G., Atukwase, A., Tibagonzeka, J. E., Apil, J., Wambete, J. M., Atekyereza, P. R., ... & Muyonga, J. H. (2020). On-farm evaluation of the effectiveness of improved postharvest handling of maize in reducing grain losses, mold infection, and aflatoxin contamination in rural Uganda. *African Journal of Food, Agriculture, Nutrition and Development*, *20*(5), 16522–16539. https://doi.org/10.18697/ajfand.93.19790

American Association for Agricultural Education (AAAE). (2023). *AAAE research values*. Accessed at: https://aaea.wildapricot.org/resources/Documents/FOR%20ONLINE%20(8.5%20x%2011)%20-%20AAAE%20Research%20Values.pdf

Andenoro, C. A., Baker, M., Nicole L. P., Stedman, L. P. N., & Weeks, P. P. (2016). Research priority 7: Addressing complex problems. In G. Roberts., A. Harder., & T. M. Brashears, (Eds.), *AAAE national research agenda:2016-2020* (pp. 57–66). Gainesville, Florida, United States.

Anderson, A. (2023). *Pedology as a scientific, teachable, and artistic discipline in the 21st century* [Doctoral Dissertation, Iowa State University]. Theses and Dissertations. https://dr.lib.iastate.edu/handle/20.500.12876/3wxae0ov

Anderson, J. R., Feder, G. & Ganguly, S. (2006). *The rise and fall of training and visit extension: An Asian mini drama with an African epilogue*. Washington, DC: The World Bank.

Apanovich, N., & Lenssen, A. W. (2018). Cropping systems and soil quality and fertility in south-central Uganda. *African Journal of Agricultural Research*, *13*(15), 792–802. https://academicjournals.org/journal/AJAR/article-full-text-pdf/35FD0A756634.pdf

Asasira, G., Karubanga, G., Okry, F., Kibwika, P., & Agea, J.G. (2019). How video attributes influence farmer learning about maize postharvest handling practices and technologies in Kakumiro district, Uganda. *International Journal of Agricultural Research Innovation & Technology 9*(1), 58–65. https://doi.org/10.3329/ijarit.v9i1.42950

Asimo, A. E., Kigozi, J., Kambugu, R., Brumm, T., Ikendi, S., & Somers., R. M. (2024, April 22–25). *Design, construction, fabrication, and testing of an indirect heated biomass grain dryer appropriate for low-income farmers* (Poster presentation). AIAEE Annual Conference, Orlando, Florida, United States.

Banige, D., Ikendi, S., Somers, R. M., Asimo, A. E., Kitayimbwa, R., & Kabbale, F. (2024a, February 3–6). *Approaches educators use to implement school-based agricultural education in Uganda* (Poster presentation). Southern Region of the AAAE Conference. Atlanta, Georgia, United States. https://www.researchgate.net/publication/377965521

Banige, D., Ikendi, S., Somers, R. M., Asimo, A. E., Kitayimbwa, R., & Kabbale, F. (2024b, February 3–6). *Contributions of SBAE to scholarship of agriculture education and lifelong learning* (Poster presentation). Southern Region of the AAAE Conference. Atlanta, Georgia, United States. https://www.researchgate.net/publication/377965541

Bbosa, D., Brumm, T. J., Bern, C. J., Rosentrater, K. A., & Raman, D. R. (2017). Evaluation of hematic maize storage in 208 liter (55 gal) steel barrels for smallholder farmers. *Transactions of the ASABE*, *60*(3), 981–987. https://doi.org/10.13031/trans.12044

Bbosa, D., Brumm, T. J., Bern, C. J., Rosentrater, K. A., & Raman, D. R. (2020). Effect of blending amaranth grain with maize kernels on maize weevil control during storage. *Transactions of the ASABE*, *63*(2), 401–406. https://doi.org/10.13031/trans.13614

Bisikwa, J., Nampala, P., Nsibo, D. L., Kwikiriza, N., Bukenya, C., Otim, M. H., Kapting, I., Kabuye, F., & Felix, J. (2022). Assessment of Striga hermonthica infestation and effectiveness of current management strategies in maize-based cropping systems in eastern Uganda. *African Crop Science Journal*, *30*(4), 525–538. https://doi.org/10.4314/acsj.v30i4.10

Brumm, T. J., Bern, C. J., & Webber, D. F. (2021). Hermetic storage of maize grain in repurposed food oil containers to control maize weevils. *Journal of Stored Products and Postharvest Research*, *12*(2), 42–46. https://doi.org/10.5897/JSPPR2021.0316

Bulyaba, R., Lenssen, A., Moore, K., & Semalulu, O. (2020). Limestone application effects on common bean (*Phaseolus vulgaris L.*) yield and grain iron and zinc concentration on a Ferralsol soil in Uganda. *African Journal of Agricultural Research 16*(12), 1652–1664, https://academicjournals.org/journal/AJAR/article-full-text-pdf/36B753165527.pdf

Butler, L. M., & Acker, G. D. (2015). Epilogue: The partnership today and looking towards the future. In L. M. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 255–268). Kumarian Press.

Butler, L. M., & McMillan, D. E. (2015). *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda*. Kumarian Press.

Byaruhanga, L. A. (2016). *Effect of school garden food production on nutrient adequacy and nutrition status of children in Namasagali primary school in rural Kamuli District, Uganda* [Master's Thesis, Kenyatta University]. Kenyatta University Institutional Repository. http://ir-library.ku.ac.ke/handle/123456789/17759

Center for Sustainable Rural Livelihoods. (2015). *Your passion, their transformation: 2015 donor impact report*. Iowa State University. Ames, Iowa, United States. Accessed at: https://www.csrl.cals.iastate.edu/files/inline-files/2015%20Annual%20Report.pdf

Center for Sustainable Rural Livelihoods. (2017). *About CSRL*. Iowa State University. Ames, Iowa, United States. Accessed at: https://www.csrl.cals.iastate.edu/about-csrl

Duerfeldt, K., Tusiime, S., & Nonnecke, G. (2016). Impact of sack gardening by youth in a Ugandan school garden program. *Horticultural Science 51*(9), S371–S372. https://doi.org/10.21273/HORTSCI.51.9S.S1

Edwards, S., & Araya, H. (2011). *How to make and use compost. Climate change and food systems resilience in Sub-Saharan Africa*. Rome Italy: FAO.

Fadairo, O., Williams, P. A., & Nalwanga, F. S. (2019). Perceived livelihood impacts and adaptation of vegetable farmers to climate variability and change in selected sites from Ghana, Uganda, and Nigeria. *Environment, Development and Sustainability*, 22(2020), 6831–6849. https://doi.org/10.1007/s10668-019-00514-1

Feder, G., Slade, R. H., & Sundaram, A. K. (1986). The training and visit extension system: An analysis of operations and effects. *Agricultural Administration*, *21*(1), 33–59. https://doi.org/10.1016/0309-586X(86)90056-7

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme, and World Health Organization. (2023). *The state of food security and nutrition in the World 2023.* https://doi.org/10.4060/cc3017en

Freire, P. (2018). *Pedagogy of the oppressed*. Bloomsbury Publishing.

Gallaher, C. M., WinklerPrins, A. M. G. A., Njenga, M., & Karanja, N. K. (2015). Creating space: Sack gardening as a livelihood strategy in the Kibera slums of Nairobi, Kenya. *Journal of Agriculture, Food Systems, and Community Development, 5*(2), 155-173. https://doi.org/10.5304/jafscd.2015.052.006

Goettsch, L. H., Lenssen, A. W., Yost, R. S., Luvaga, E. S., Semalulu, O., Tenywa, M., & Mazur, R. E. (2016). Improved production systems for common bean on Phaeozem soil in south-central Uganda. *African Journal of Agricultural Research*, *11*(46), 4796–4809. https://doi.org/10.5897/AJAR2016.11760

Hamba, S., Kasule, F., Mayanja, I., Biruma, M., Natabirwa, H., Nasirumbi S. L., Rubin, D., Occelli, M., & Adikin, S. (2024). Farmer-preferred traits and variety choices for finger millet in Uganda. *Frontiers in Sustainable Food Systems*, *8*, 1282268. https://doi.org/10.3389/fsufs.2024.1282268

Headey, D., & Ruel, M. (2023). Food inflation and child undernutrition in low and middle-income countries. *Nature Communications*, *14*(1), #5761. https://doi.org/10.1038/s41467-023-41543-9

Hedden, S., Rafa, M., & Moyer, J. D. (2018). *Achieving food security in Uganda*. USAID, Accessed at: http://drupalwebsitepardee.s3.amazonaws.com/pardee/public/Pardee_Food_Security_report_v1.pdf

Ikendi, S. (2022, May 16–19). *Developing school-based agriculture education through school gardens* (Poster presentation). National American Association for Agricultural Education Conference. Oklahoma City OK, United States. http://aaae.agedweb.org/downloadfile.asp?ID=4996

Ikendi, S. (2023). Ecological conservation, biodiversity, and agricultural education as integrated approaches for envisioning the future of sustainable agriculture in North America. *International Journal of Sustainable Development & World Ecology, 30*(2), 152–163. https://doi.org/10.1080/13504509.2022.2127032

Ikendi, S., & Retallick, M. (2023a, April 26–29). *Exported through the theory of change: An inquiry into the compatibility of the U.S. land grant philosophy in Uganda* (Proceedings, pp. 358–361). AIAEE Annual Conference. Guelph, Ontario, Canada. https://www.researchgate.net/publication/371256111

Ikendi, S., & Retallick, M. (2023b, May 15–18). *Improving managerial and leadership effectiveness in multistakeholder organizations* (Paper Proceedings, pp. 636–655). National AAAE Conference. Raleigh, North Carolina, United States. https://www.researchgate.net/publication/371255708

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2023a). Nutrition education centers: A community–based approach to management of malnutrition. *Journal of Agriculture, Food Systems, and Community Development, 13*(1), 9–15. https://doi.org/10.5304/jafscd.2023.131.010

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2023b). Does participation in livelihood education programs impact household food security? A comparative study in rural Uganda. *Journal of Agriculture, Food Systems, and Community Development, 13*(1), 235–265. https://doi.org/10.5304/jafscd.2023.131.009

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2023c September 18–20). *Towards nutrition security among mothers and children through livelihood programs* (Poster presentation). Western Region of the AAAE Conference. Logan, Utah, United States. https://www.researchgate.net/publication/374153419

Ikendi, S., Owusu, F., Masinde, D., Oberhauser., & Bain, C. (2024, April 22–25). *Improving household dietary diversity and caloric intake through livelihood education interventions in eastern Uganda* (Poster presentation). AIAEE Conference, Orlando, FL. United States.

Ikendi, S., Retallick, M. S., Nonnecke, G. R., & Kugonza, D. R. (2023). Influence of school garden learning approach on academic development of global service-learners. *Journal of Agricultural Education, 64*(4), 159–179. https://doi.org/10.5032/jae.v64i4.167

Iowa State University. (2016). *2017–2022 strategic plan*. Iowa State University, Office of the President. Accessed at: https://strategicplan.iastate.edu/iowa-state-university-strategic-plan-2017-2022.pdf

Jjagwe, G., Kibwika, P., Mazur, R., & Sseguya, H. (2022). The role of smallholder bean farmers in determining farm gate prices for beans in Uganda. *Agriculture & Food Security*, *11*, #45. https://doi.org/10.1186/s40066-022-00380-7

Kabango, F., Byalebeka, J., Semalulu, O., Lenssen, A. W., Majaliwa, M. J. G., & Kyebogola, S. (2022). Effect of applying low rates of agricultural lime and chicken manure on selected soil properties on Ferralsols of Lake Victoria Agro-Ecological Zone, Uganda. *Journal of Agricultural Chemistry, 11*, 240–257. https://doi.org/10.4236/jacen.2022.114017

Kasule, F., Kakeeto, R., Tippe, D. E., Okinong,D., Aru, C., Wasswa, P., Chrispus A.O Oduori, C. A. O., & Adikini, S. (2023). Insights into finger millet production: Constraints, opportunities, and implications for improving the crop in Uganda. *Journal of Plant Breeding and Crop Science 15*(4), 143–164. https://doi.org/10.5897/JPBCS2023.1018

Kasule, F., Wasswa, P., Mukasa, S. B., Okiror, A., & Mwang'ombe, A. W. (2020b). Effective isolation distance for prevention of cassava virus infections in Uganda. *African Crop Science Journal*, *28*(s1), 1–13. https://doi.org/10.4314/acsj.v28i1.1S

Kasule, F., Wasswa, P., Mukasa, S. B., Okiror, A., Nghituwamhata, S. N., Rono, E. C., Mukuze, C., & Mwang'ombe, A. W. (2020a). Farmer preference of cassava cultivars in eastern Uganda: A choice beyond disease resistance. *Agricultural Science*, *2*(2), 169–177. https://doi.org/10.30560/as.v2n2p169

Kheleli, M. R., Zhang, J., Mofolo, T. C., & Mwandiringana, E. (2021). Adaptation to climate change: Status, household strategies and challenges in Lesotho. *International Journal of Scientific Advances, 2*(3), 365–370. https://doi.org/10.51542/ijscia.v2i3.21

Kollie, W. S., Byalebeka, J., Basamba, T. A., Adukpo, D. C., & Eneku, J. P. (2023). Linkages between soil acidity, soil plant nutrients and land use on Ferralsols in central Uganda. *International Journal of Plant & Soil Science*, *35*(18), 1395–1407. https://doi.org/10.9734/IJPSS/2023/v35i183406

Kreimer, A., Collier, P., Scott, C. S., & Arnold, M. (2000). *Uganda, post-conflict reconstruction: Country case study series*. World Bank Publications.

Kwikiiriza, S. (2022). *Evaluation of horticultural practices for tropical squash production and marketing among smallholder youth farmers in Kamuli, Uganda* [Master's Thesis, Iowa State University]. Theses and Dissertations. https://dr.lib.iastate.edu/handle/20.500.12876/Nr1VX8nz

Kyebogola, S., Burras, L. C., Miller, B. A., Semalulu, O., Yost, R. S., Tenywa, M. M., Lenssen, A. W., Kyomuhendo, P., Smith, C., Luswata, C. K., Majaliwa, M. J. G., Goettsch, L., Colfer, C. J. P., Mazur, R. E. (2020). Comparing Uganda's indigenous soil classification system with World Reference Base and USDA Soil Taxonomy to predict soil productivity. *Geoderma Regional 22*. https://doi.org/10.1016/j.geodrs.2020.e00296

Kyebogola, S., Semalulu, O., Lenssen, A. W., Yost, R. S., Kyomuhendo, P., Tenywa, M. M., & Mazur, R. E. (2021). Exploring on-farm additive common bean yield potential to organic and mineral fertilizers on contrasting soils of Buganda Catena. *African Journal of Agricultural Research*, *17*(3), 463–471. https://doi.org/10.5897/AJAR2020.15395

Lege, L. M., & Carpenter-Boggs, L. A. (2020). Producer knowledge, attitudes, and practices for dry beans and biological nitrogen fixation in Kamuli district, Uganda. In M. A. Sutton, K. E. Mason, A. Bleeker, W. K. Hicks, C. Masso, N. Raghuram, S. Reis, & M. Bekunda (Eds), *Just enough nitrogen: Perspectives on how to get there for regions with too much and too little nitrogen* (pp. 115–123). Springer.

Malual, J. D., & Mazur, R. E. (2022). Social capital and food security in post-conflict rural Lira District, northern Uganda. *Disasters*, *46*(1), 80–94. https://doi.org/10.1111/disa.12465

Martin, T. (2018). *Individual capacities (human capital) of the Tusubila crafts group* [Master's Thesis, Iowa State University]. Creative Components. https://lib.dr.iastate.edu/creativecomponents/85

Masambuka-Kanchewa, F., Lamm, A., & Qu, S. (2022). Exploring the impact of agricultural policies on the documentation and sharing of indigenous knowledge in Sub-Saharan Africa. *Journal of Agricultural Extension and Rural Development 4*(4), 173–182. https://doi.org/10.5897/JAERD2022.1331

Masinde, D., & McMillan, D. E. (2015). Starting where the people are. In M. L. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 111–144). Kumarian Press.

Masinde, D., Butler, M. L., & Mazur, R. (2015). Getting started. In L. M. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 57–81). Kumarian Press.

Masinde, D., McMillan, E. D., Rothschild, M., & Nonnecke, G. (2015). Leaving the door open to emerging needs and opportunities. In L. M. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 145–164). Kumarian Press.

Mayanja, I. K., Kigozi, J., Kawongolo, J., & Brumm, T. (2018). Design, fabrication, and testing of a pedal-operated maize grain cleaner. *Journal of Advances in Food Science 5*(3), 105–111. https://www.ikppress.org/index.php/JAFSAT/article/view/4321

Merriam, S. B., & Baumgartner, L. M. (2020). *Learning in adulthood: A comprehensive guide*. John Wiley & Sons.

Ministry of Agriculture Animal Industry and Fisheries (MAAIF), (2000). *The National Agricultural Advisory Services master document.* Entebbe, Uganda.

Ministry of Agriculture, Animal Industry and Fisheries & Ministry of Health. (2004). *Uganda food and nutrition strategy and investment plan: Draft final*. Kampala, Uganda.

Ministry of Finance, Planning, and Economic Development [MFPED] (2000*). Poverty reduction strategy paper: Uganda's poverty eradication action plan.* Kampala: Uganda & IMF. https://www.imf.org/external/NP/prsp/2000/Uga/01/

Mohan, S. V., Hemalatha, M., Amulya, K., Velvizhi, G., Chiranjeevi, P., Sarkar, O., Kumar, A. N., Krishna, K. V., Modestra, J. A., Dahiya, S., Yeruva, D. K., ButtiS. K., Sravan, S. J., Chatterjee, S., & Kona, R. (2020). Decentralized urban farming through keyhole garden. *Materials Circular Economy*, *2*, 12. https://doi.org/10.1007/s42824-020-00011-1

Montgomery, D. R. (2021). Soil health and the revolutionary potential of conservation agriculture. In A. Kassam & A. L. Kassam. (Eds.), *Rethinking food and agriculture* (p. 219–229). Woodhead Publishing.

Muroyiwa, B., & Ts'elisang, L. T. (2021). Factors affecting food security of rural farmers in Lesotho: The case of keyhole gardeners in Leribe District. *Journal of Agribusiness & Rural Development*, *59*(1), 77–90. http://doi.org/10.17306/J.JARD.2021.01397

Museveni, K. Y. (2000). *What is Africa's problem?* The University of Minnesota Press.

Muyonga, J. H., Ugen, M., Bisikwa, J., Nakimbugwe, D., Masinde, D., Bbemba, J., & Wambete, J. (2010). *Promoting production and utilization of grain amaranth for improved nutrition and health in Uganda. Annual progress report*. McKnight Foundation.

Nonnecke, G., Masinde, D., Byaruhanga, L., Lutwama, D., & Acker, D. (2016). Using school gardens to support school feeding programs at elementary Schools in Uganda [Poster presentation]. *HortScience*, *51*(9S), S370. https://doi.org/10.21273/HORTSCI.51.9S.S1

Nonnecke, G., McMillan, D. E., Kugonza, D., & Masinde, D. (2015). Leaving the doors open to new beneficiaries. In L. M. Butler & D. E. McMillan (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 165–189). Kumarian.

Office of the Prime Minister (2020). *Uganda nutrition action plan (2020–2025): Leaving no one behind in scaling up nutrition actions*. Kampala, Uganda. Accessed at: https://scalingupnutrition.org/sites/default/files/2022-06/national-nutrition-plan-uganda.pdf

Okii, D., Badji, A., Odong, T., Talwana, H., Tukamuhabwa, P., Magdalena, W., Gepts, P., & Mukankusi, C. (2019). Responses to selection for yield traits and key diseases among common bean genetic pyramids across locations. *Journal of Crop Improvement*, *33*(6), 834–854. https://doi.org/10.1080/15427528.2019.1673270

Opio-Odongo, J. M. A. (1992). *Designs on the land. Agricultural research in Uganda, 1980–1990*. ACTS

Pound, B., & Conroy, C. (2017). The innovation systems approach to agricultural research and development. In S. Snapp & B. Pound. (Eds.), *Agricultural systems: Agroecology and rural innovation for development* (pp. 371–405). Academic Press.

Rogers, E. M., (2003). *Diffusion of innovations*. Free Press.

Schunk, D. (2020). *Learning theories: An educational perspective*. Pearson.

Semana, A. R. (1999). *Agricultural extension services at crossroads: Present dilemma and possible solutions for future in Uganda*. Accessed at: https://www.codesria.org/IMG/pdf/Semana.pdf

Sseguya, H., Mazur, R. E., & Flora, C. B. (2018). Social capital dimensions in household food security interventions: Implications for rural Uganda. *Agriculture and Human Values, 35*(1), 117–129. https://doi.org/10.1007/s10460-017-9805-9

Sseguya, H., Mazur, R. E., Wells, B., & Matsiko, F. (2015). Quality of participation in community groups in Kamuli District, Uganda: Implications for policy and practice. *Community Development*, *46*(1), 14–25. https://doi.org/10.1080/15575330.2014.971036

Ssemakula, E., & Mutimba, J. K. (2011). Effectiveness of the farmer-to-farmer extension model in increasing technology uptake in Masaka and Tororo Districts of Uganda. *South African Journal of Agricultural Extension*, *39*(2), 30–46. https://doi.org/10.4314/sajae.v39i2

Sserunjogi, M., Bern, C. J., Brumm, T. J., & Maier, D. E. (2021). Periodic disturbance time interval for suppression of the maize weevils, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in stored maize (*Zea mays L.*). *Journal of Stored Products Research*, *94*, 101875. https://doi.org/10.1016/j.jspr.2021.101875

Taku-Forchu, N. (2019). *Linking smallholder farmers to markets: The role of extension in market information for poverty reduction in Fako, Cameroon* [Master's Thesis, Iowa State University]. https://dr.lib.iastate.edu/handle/20.500.12876/31514

Taku-Forchu, N., Lambert, M. D., Retallick, M. S., Ulmer, J. D., & Opit, G. P. (2023). Drivers of farmers' adoption of hermetic storage bags in Ghana. *Journal of International Agricultural and Extension*, *30*(2), 116–136. https://doi.org/10.4148/2831-5960.1064

Taku-Forchu, N., Qu, S., Lambert, M. D., Retallick, M. S., Ulmer, J. D., & Opit, G. P. (2023). Maize farmers' use, preference, and trustworthiness of information sources and communication channels in Dormaa, Ghana: A gender comparison. *Journal of Applied Communications*, *107*(3), #4. https://doi.org/10.4148/1051-0834.2479

Thompson, P. B. (2017). *The spirit of the soil: Agriculture and environmental ethics*. Routledge.

Tibagonzeka, J. E., Akumu, G., Kiyimba, F., Atukwase, A., Wambete, J., Bbemba, J., & Muyonga, J. H. (2018). Postharvest handling practices and losses for legumes and starchy staples in Uganda. *Agricultural Sciences*, *9*(1), 141–156. https://doi.org/10.4236/as.2018.91011

Tukamuhabwa, P., Obua, T., Namara, N., Kabayi, P., & Yiga, G. (2019). *Soybean research and development in Uganda: Highlights 2002–2018.* Makerere University: Kampala.

Tumutegyereize, P., Oluk, I., Kigozi, J., Mayanja, I., Buyinza, T., & Mbeiza, M. (2022). Assessing the effect of access on the use of improved seed cleaning technologies: Challenges and opportunities among farmers in the Kamuli district-Uganda. *International Journal of Postharvest Technology and Innovation*, *8*(2-3), 243–256. https://doi.org/10.1504/IJPTI.2022.121943

Tusiime, S. M. (2019). *Current status and prospects of tomato seed production and distribution in Uganda* [Doctoral Dissertation, Iowa State University]. https://dr.lib.iastate.edu/handle/20.500.12876/31772

Tusiime, S. M., Nonnecke, G. R., Masinde, D. M., & Jensen, H. H. (2019). Evaluation of horticultural practices for sustainable tomato production in eastern Uganda. *HortScience*, *54*(11), 1934–1940. https://doi.org/10.21273/HORTSCI14277-19

Uganda Bureau of Statistics (2017). *The National Population and Housing Census 2014—Area specific profile series: Kamuli District*. Kampala, Uganda.

Uganda Bureau of Statistics. (2016). *The National Population and Housing Census 2014—Main report.* Kampala, Uganda.

United Nations. (2015). *Take action for the sustainable development goals*. Accessed at: https://www.un.org/sustainabledevelopment/sustainable-development-goals/.

von Grebmer, K., Bernstein, J., Wiemers, M., Reiner. L., Bachmeier, M., Hanano, A., Chéilleachair, N. R., Foley, C., Sheehan, T., Gitter, S., Larocque, G., & Fritschel, H. (2023). *2023 global hunger index: The power of youth in shaping food systems.* Welthungerhilfe, Concern Worldwide. https://www.globalhungerindex.org/pdf/en/2023.pdf

Waaswa, A., Nkurumwa, A. O., Kibe, A. M., & Kipkemoi, J. N. (2021a). Climate-smart agriculture and potato production in Kenya. *Climate and Development*, *14*(1), 75–90. https://doi.org/10.1080/17565529.2021.1885336

Waaswa, A., Nkurumwa, A. O., Kibe, A. M., & Kipkemoi, N. J. (2021b). Communicating climate change adaptation strategies: Climate-smart agriculture information dissemination pathways among smallholder potato farmers in Gilgil Sub-County, Kenya. *Heliyon*, *7*(8), e07873. https://doi.org/10.1016/j.heliyon.2021.e07873

Waaswa, A., Nkurumwa, A. O., Kibe, A. M., & Ng'eno, J. K. (2021c). Understanding the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya. *Discover Sustainability*, *2*, Article #41. https://doi.org/10.1007/s43621-021-00050-x

Wanyakha, M. T. (2016). *Germplasm in eastern Uganda: Community participation in varietal identification and characterization of xanthosoma sagittifolium (L.) schott and colocasia esculenta (L.) schott* [Master's Thesis, University of California Davis]. Dissertations & Thesis. https://www.proquest.com/dissertations-theses/germplasm-eastern-uganda-community-participation/docview/1845027012/se-2

Wokibula, A. R., & Westgate, E. M. (2016, November 6-9). *Green manure intercropping systems to boost maize yields: A case study in Kamuli district, Uganda* (Poster presentation). American Society of Agronomy. Phoenix, Arizona, United States. https://scisoc.confex.com/scisoc/2016am/webprogram/Paper100198.html