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Livestock Extension Education: A Livelihoods Revitalization Strategy in Rural Uganda

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Abstract

The Ugandan government has relentlessly partnered with universities and philanthropic organizations in building the human capacities of livestock farmers to improve their herd production. The study investigated the impact of the livestock programs of Iowa State University (ISU) of the United States through its Center for Sustainable Rural Livelihoods and ISU Uganda program in Uganda. The study determined the influence of livestock training programs on the adoption of sustainable livestock production practices between 2014 to 2018 commensurate with the 2014 to 2019 strategic plan impact evaluation. We sampled 454 households, of whom 366 (80.6%) were livestock farmers. Among livestock farmers, 174 (47.5%) participated in livestock training programs. Farmers mostly trained in local chickens, exotic/layer chickens, and piggery; average in goats and feeding/feed formulation; but less in forage production and marketing/gross margin analysis. The frequency of attendance was low with 80.5% attending one to seven of 21 maximum times. In assessing knowledge comprehension and retention, we established an average score of 63.6% among all trainees. In production trends, 93.2% were involved in production before 2014, 76.0% were active in production by 2018, and up to 23.0% (re)joined a livestock enterprise between 2014 and 2018. Households who (re)joined production were associated with participation in livestock training and received inputs like breeding animals, water tanks, and feeds. The study recommends continuous training of farmers and upgrading service providers, establishment of resource centers, and engaging policymakers on policies on training and capacity-building efforts. Routine monitoring and evaluation of the training materials and farmers.

Introduction and Background

Revitalization of the livelihoods of rural communities is an important strategy for achieving the vision for an African renaissance as outlined in the 2063 African Union agenda (African Union, 2015). Investing in livestock extension programs is one of the most plausible ways of improving the human capital of livestock farmers in making informed production decisions. In Sub-Saharan Africa, rearing small livestock such as poultry, small ruminants like goats, and non-ruminants like pigs is a strategic pathway to poverty reduction (Flax et al., 2023; FAO, 2017; Owen et al., 2020; Ouma et al., 2015; Van Tassell et al.,

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2023). Livestock is an alternative insurance in case of crop failure as animals and their products can be sold off to buy food and/or seeds for the next season (Bell et al., 2021; Machebe et al., 2023). Farmers who embrace livestock in their enterprise diversification, especially in rural Uganda experience less poverty because of diversified income and are found to be food secure (Bain et al., 2020; Ikendi, Owusu et al., 2023a; 2024a) with healthier mothers and children (Ikendi, Owusu et al., 2023b; Kalinaki, 2025). Start-up capital is generally low for limited-resource communities and generous organizations have complemented African governments in boosting human capital and poverty alleviation through livestock extension education (Ali et al., 2024; Masinde, McMillan et al., 2015; Okello et al., 2023; Ouma et al., 2024; Thorne & Conroy, 2017; Van Tassell et al., 2023).

The Kamuli district of Uganda, our case study, has been a beneficiary of philanthropists from the global north in development of the livestock integration programs (Masinde, McMillan et al., 2015). Earlier in 2000, the government of Uganda embarked on developing the extension sector; however, limited extension agents were a major problem (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF] & Ministry of Health [MoH], 2004). Part of the strategy in the comprehensive Uganda Food and Nutrition Strategy and Investment Plan of that time included the promotion of public-private partnerships, a strategy that was adopted and adapted by Iowa State University to implement livelihood interventions in Uganda. A trio partnership was formed in 2003 amongst Iowa State University through the Center for Sustainable Rural Livelihoods (CSRL), Makerere University Kampala, and local non-governmental organizations (NGOs) to help end hunger in Uganda.

Between 2004–2014, the participating NGO was Volunteer Efforts for Development Concerns (VEDCO), but since then Iowa State University Uganda Program (ISU–UP) has been the home for the CRSL operations in Uganda (Butler & Acker, 2015; Ikendi & Retallick, 2023a). The CSRL/VEDCO partnership operated in tandem with the National Agricultural Advisory Services (NAADS) model of a farmer-to-farmer group approach with community-based Rural Development Extensionists, and Community and Nutrition Health Workers as change agents (Masinde, Butler et al., 2015). The food security groups were organized with their local leaders elected and governed by their constitution, which eased the diffusion of relevant technologies and harnessed community capital for their community development (Sseguya et al., 2015; 2018). In 2014, CSRL launched a comprehensive capacity development program illustrated in Figure 1 (CSRL, [2017] as described in Ikendi, Owusu et al., 2023a, pp. 237–239), which touches the lives of people from pregnancy to seniors through different livelihood education programs. The human capacity development model was the essence of the rebirth of knowledge and livelihood strategies within communities by empowering households with all-rounded strategies in agronomy and postharvest; nutrition, infant feeding, and public health; youth entrepreneurship and service-learning through school gardening, and food and nutrition support groups and community innovations. Despite the many livelihood education programs, this study focused on livestock programs.

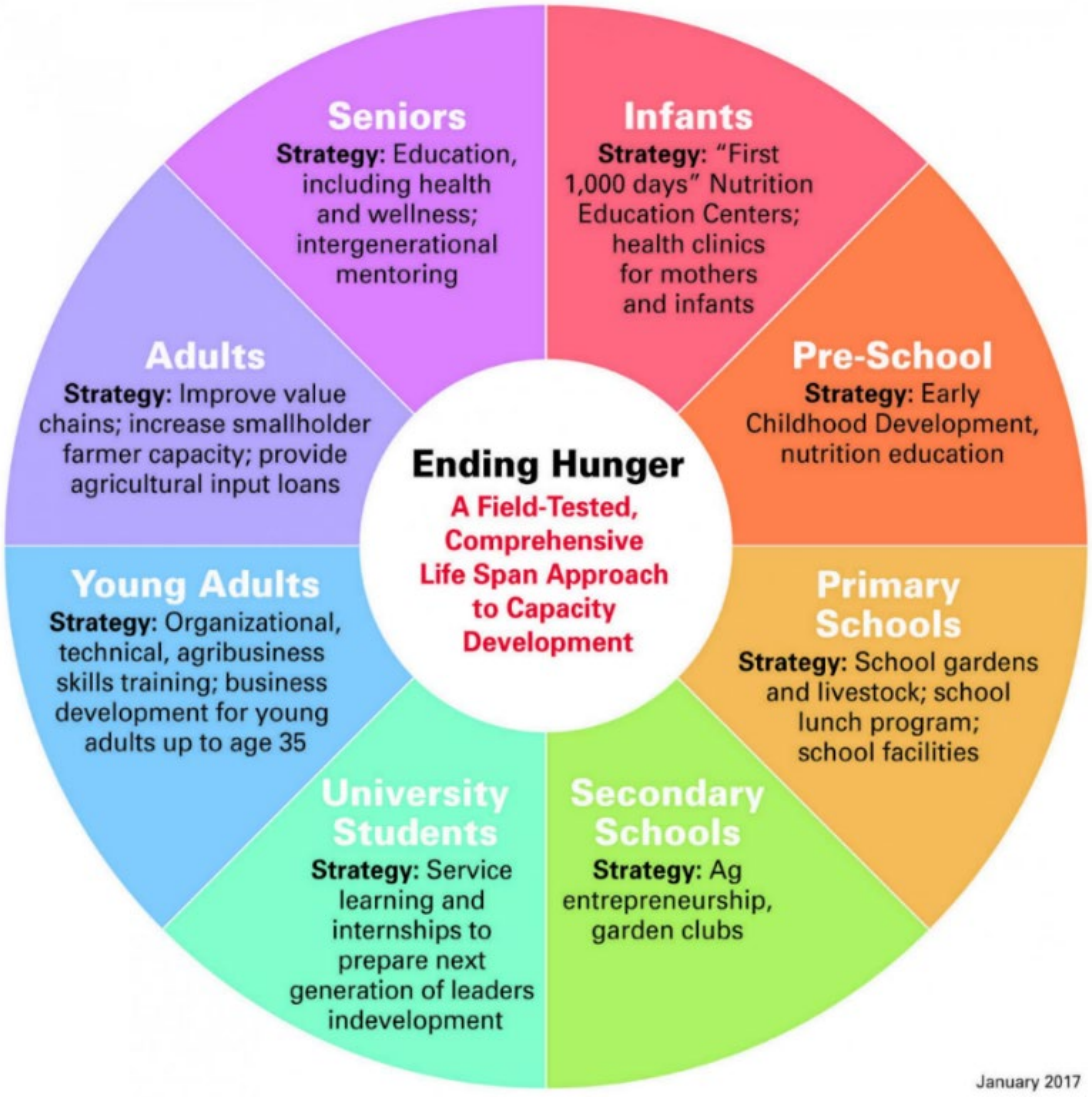
The CSRL/ISU-UP Livestock Extension Education Interventions

The goal of the CSRL/ISU–UP livestock integration program is to enhance household incomes and increase access of community members to animal-source protein through the provision of education in sustainable livestock production and management practices (Masinde, McMillan et al., 2015). The program dates back to 2006 with the initiation of egg production in Namasagali primary school, and beehives for honey production under the global service-learning and school garden programs. Although the livestock program expanded over the years since 2006, our assessment study focused on the period between 2014 through 2018, commensurate with the impact evaluation of the 2014/2019 first CSRL/ISU–UP partnership strategic plan (Ikendi & Retallick, 2023a, p. 647). At the launch of the CSRL/ISU–UP partnership in 2014, the livestock integration program expanded to include malnutrition-rehabilitated mothers of the nutrition education centers (NECs) and youth in commercial egg production, to increase their livelihood strategies (Masinde, McMillan et al., 2015). The NECs are rehabilitation centers for at-risk-for-malnutrition pregnant and breastfeeding mothers, infants, and children of 0 to 59 months of age, are rehabilitated through nutrition

therapy composed of nutrient-dense porridge (Ikendi, Owusu et al., 2023b; 2023c; Masinde, McMillan et al., 2015). Mothers also participate in livelihood programs including livestock integration to improve their health and production strategies for food and nutrition security.

Figure 1

The CSRL/ISU–UP Field-Tested Comprehensive Lifespan Approach to Capacity Development



Source: CSRL (2017) as described in Ikendi, Owusu et al. (2023, pp. 237–239).

The livestock integration program also supports youth, both in-school, and out-of-school, and these received their first batch of layer chicks in 2015 (Masinde, McMillan et al., 2015). In 2016, the livestock program expanded further to include piggery and goat projects, expanding on previous programs before 2014 (Ampaire & Rothchild, 2010a; 2010b; 2011; Walugembe et al., 2014). In goat production, Mubende bucks (male goats) were selected to improve the local goats through crossbreeding. These Mubende bucks were chosen for their productivity due to their size and tolerance to tick-borne diseases and worms (Kugonza et al., 2014). It was further attested that Mubende bucks are good in reproduction when properly bred at a ratio of one male to 30 females can increase the farm flock to up to 50 animals a year, translating into a financial breakthrough. In local chicken production, the livestock program opted to improve the hatchability of local chickens by introducing kuroilers and ducks (Semahoro et al., 2018). These kuroilers

are good at laying eggs but could not hatch their eggs and ducks were experimented with and found capable of hatching the eggs both from local chickens and kuroilers. Additionally, in 2016, the program embarked on the construction of livestock water tanks (i.e., above-ground tanks with a capacity of 6,000 liters and below-ground tanks for 20,000 liters) for selected farmers (CSRL, 2016). The program cost-shares with beneficiary farmers in the construction of livestock water tanks, where farmers provide raw materials like roofing timber, burnt earth-baked bricks, and sand, and food for engineers; and the program provides labor costs, cement, dam liners, and iron sheets, among other logistics. Water from the livestock tanks is used for animals, household consumption, and crops, through small-scale irrigation. Similarly, CSRL constructed the Mpirigiti Rural Training Center, with a livestock demonstration farm, managing to arrange livestock projects such as layer chickens, pigs, goats, and cattle for community learning purposes (Ikendi & Retallick, 2023a, p. 645). Other veterinary services are provided at a minimal cost, including vaccinations and treatments for the animals through livestock specialists and animal health workers.

Purpose and Objectives of the Study

The purpose of this study was to determine the rate at which livestock extension education and intervention programs influenced the adoption of sustainable livestock production and management practices for improving household livelihoods. The purpose was achieved by comparing the livestock households who participated in the training programs and those who never participated in the training, from 2014 through 2018. This assessment period was commensurate with the CSRL/ISU–UP impact evaluation of the program's 2015/2019 strategic plan whose outcome provided the basis for the 2020/2024 strategic plan conducted through Thinktank in the fall of 2019. This study aligns with the American Association for Agricultural Education (AAAE) research values of advancing public knowledge of Agriculture, Food, and Natural Resources systems, specifically "measuring the impacts on producer and/or community outreach" (AAAE, 2023, p. 8). This study was based on four main objectives:

1. Determine the frequency of household participation in livestock extension education.
2. Assess the knowledge comprehension and retention of households in livestock extension education.
3. Establish the influence of livestock extension education on trends in livestock production.
4. Estimate the household livestock production capacity across the years 2014 through 2018.

Conceptualization of Technology Transfer and Adoption

Our study was founded on the change continuum for the adoption of innovations (Rogers, 2003). The services offered by extension agents such as education and monitoring of farmers' enterprises are vital in the adoption of innovations that raise livestock productivity (Ali et al., 2024; Kakungulu et al., 2025; Masinde, McMillan et al., 2015; Okello et al., 2023; Ouma et al., 2024; Thorne & Conroy, 2017; Van Tassell et al., 2023). Extension advisors are change agents, they transfer and influence the adoption of technologies and innovations. However, the adoption rates of innovations are influenced by the perception of communities and receivers relating to what is constituted in those innovations (Rogers, 2003). Similarly, acceptance of innovations is influenced by several other factors including communication channels, time, innovation design, social system, suitability of target audience, and the tactical efforts of the agents in persuading the communities to adopt the innovation (Pound & Conroy, 2017; Rogers, 2003).

Building relationships with farmers coupled with the capacity of extension advisors determines the success of outreach programs embedded in the sequential implementation of the change continuum principles. As change agents, extension advisors must work in a systematic continuum with the next role building on the previous role to achieve the desired outcomes of the intended change in communities (Rogers, 2003). The renascence of livelihoods through livestock integration programs, for instance, requires developing the need for change within the communities through needs assessment and analysis as the first step to program planning and development. The needs assessment and analysis process helps in developing

information exchange relationships through bonding with the communities in a participatory manner for effective social acceptance of the change modalities. Through the needs analysis, bonding with communities is critical in diagnosing the problem with a keen understanding of what communities want but not what agents and/or their organizations want, which is critical in influencing the adoption, implementation, and success of the innovation. Involving communities in determining their needs helps create a situation where the intended change is community-owned (Rogers, 2003). This aspect is vital because communities are involved in brainstorming the solution, a progressive movement value in community empowerment (Dewey, 1938). To accomplish the change, agents must stabilize the adoption of innovation in the communities (Rogers, 2003). Rogers asserts that agents must be aware of what and how much of the intended actions have been translated into reality. Impact aspects here are constant monitoring and evaluation of the process of implementation, output, outcome, and long-term impact.

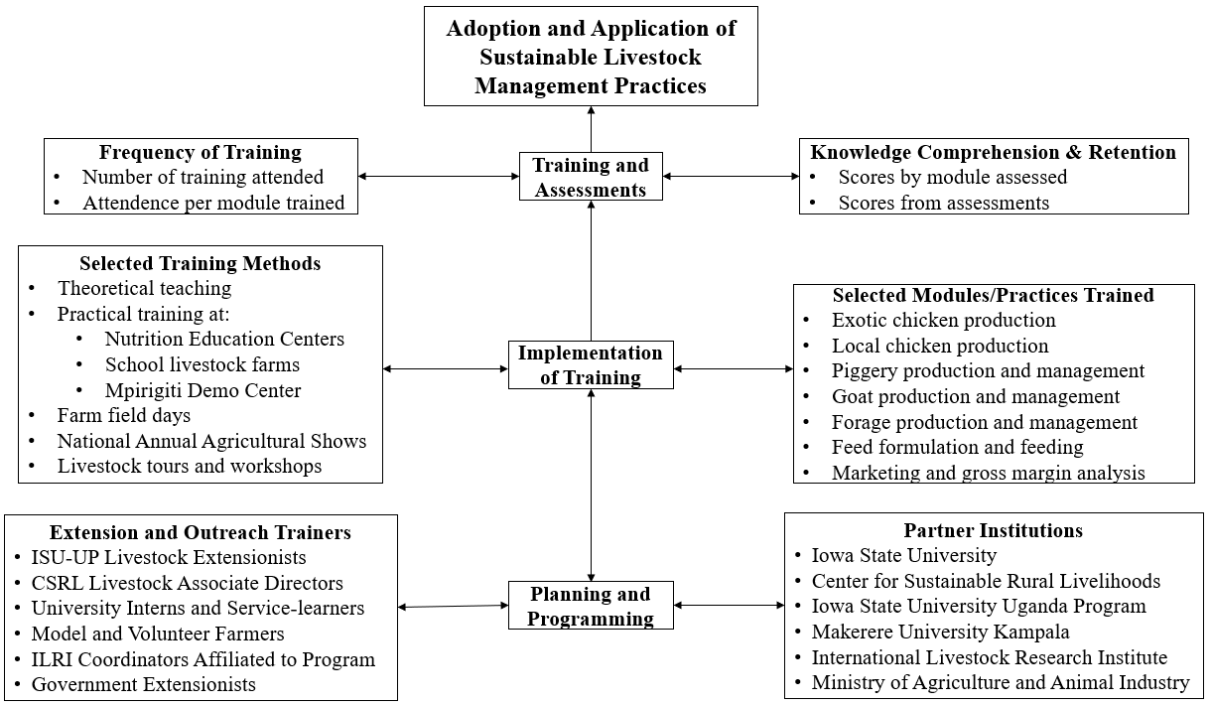
To achieve stabilization, agents must also present discontinuance reinforcement to make the communities move by themselves. Change modalities are done by influencing positive behavior within communities towards owning the implementation. Rogers posits that the last step on the change continuum is spreading the change modalities to other community members without the direct backing of agents. This action reflects a move towards sustainability at the termination of the agents–communities relationship. In his work, Rogers provided a case study of the "Sustainability 'Chicken' Davis in Nigeria" (p. 376) detailing how a change continuum and change modalities can be a success or a failure. The known facts in the case were poor poultry farming methods in eastern Nigeria that partially contributed to a severe shortage of animal-source protein foods that were key in the Nigerian national diets. Dr. "Chicken" Davis thought of introducing western layer chickens into the region to increase egg and meat production, consumption, and income, due to their high productivity. The innovation had success in implementation but failed in sustainability due to the continuous importation of both chicks and feeds for three years. The departure of Dr. Davis marked the end of the program. The disappearance of the last remnants of western chickens only left unpleasant memories. This case study depicts a lack of compatibility of innovation with the resources in the local communities.

In the transfer of innovative technologies for community development, there is a need for needs assessment and analysis and extensive extension education to build the human capital of farmers that will contribute to the program's sustainability upon the closure of direct support of the programs for organizations (Rogers, 2003). In our study, the Center for Sustainable Rural Livelihoods (CSRL) and Iowa State University Uganda Program (ISU–UP) used interactive communication systems with the intent of creating change among livestock farmers using the program livestock specialists and Community-Based Animal Health Workers (CBAHWs) of the program, and cooperating organizations, government agencies, and institutions as change agents. The CBAHWs who are mostly members of the local communities are recruited and retrained by the program to meet its operational standards in livestock education and provision of veterinary service. These CBAHWs understand the traditional norms and customs of their communities relating to livestock production systems since they live within the same communities and have a role in influencing livestock farmers toward the adoption of innovative livestock production and management systems to improve their enterprise productivity.

To boost the work of the CBAHWs, the CSRL program capitalizes on indigenous knowledge (Masinde & McMillan, 2015; Ikendi & Retallick, 2023b) and relies on scientific research findings (Acker et al., 2015; Ikendi & Retallick, 2023b) to guide the adoption of innovative technologies and the creation of extension education materials for its programs, including livestock. Together with livestock specialists, cooperating organizations, and agencies, the CBAHWs provide veterinary services like vaccinations and treatment of animals, complementing government efforts, an idea adopted by other development organizations to help farmers (Enahoro et al., 2021; Leyland et al., 2014; Van Troos et al., 2018). To foster the adoption of innovative and sustainable livestock production and management practices, continuous training and monitoring of livestock farmers are conducted in the communities (see Figure 2.).

Figure 2

Livestock Integration Extension Education Assessment Framework Designed for the Study



Abbreviations: International Livestock Research Institute (ILRI).

Methods

This study was part of a larger cross-sectional survey conducted in the Butansi and Namasagali Sub-Counties in Kamuli district, Uganda where CSRL implements livelihood programs to end hunger (see the area map in Ikendi, Owusu et al., 2023a, p. 242). Research oversight was sought and granted under IRB:18-356-01 at Iowa State University. The sampling frame was 1,503 clients who had participated in at-risk-for-malnutrition rehabilitation programs through the Nutrition Education Centers (NECs) between 2014 through 2018 (Ikendi, Owusu et al., 2023c). The livestock integration program is part of the livelihood education programs for managing malnutrition through the promotion of the consumption of animal-source proteins and related benefits of income and manure production beneficial to crops (Ikendi, Owusu et al., 2024b). The contact list of clients was provided to the research team by ISU–UP in Kamuli. A representative sample of 306 clients was established using a 95% confidence interval and a 5% margin of error. The community-based NEC trainers worked with the Co-Principal Investigator and the team of trained research assistants to locate the NEC households. The Co-PI, most of the research assistants, and all the NEC trainers are natives of the communities where the study was conducted. This aspect eased the seeking of verbal consent and data collection in the local "Lusoga" dialect and responses recorded in English. We accessed and interviewed 174 (56.9%) livestock-trained households. Our goal was to interview an additional non-trained household in a quarter-mile radius of a trained household for a comparison of livestock production and management strategies. In this attempt, we accessed and interviewed an additional 280 non-trained households, giving a total of 454 households in the study. We sorted the data to include an analysis of only households that had livestock enterprises, which we determined to be 366 (80.6%) of the 454 households.

Data Collection

For households who participated in the livestock training, we collected data on the modules trained and the number of times trained per module for seven modules considered in this study. The modules

included production and management of exotic chicken, local chicken, piggery, goats, forage, feed formulation and feeding, and marketing and gross margin analysis (see Figure 2.). We assessed knowledge comprehension and retention with a set of six questions to understand if the livestock trainees could recall what was taught and/or based on what they practiced on their livestock enterprises. The questions and the relatively correct responses were set by the research team and discussed with the program livestock specialists based on what they train their farmers. Biographical information was collected at the household level that was believed to influence farmers' participation in livestock training and the adoption and practice of sustainable livestock production and management practices. Data on livestock production trends including breeds reared since 2014; any sales made (number of heads sold); and estimated sales revenue in Ugandan currency (shillings) and converted to U.S. dollars were all collected. We further inquired for information on whether the households dropped out and/or (re)joined any of the 10 livestock enterprises we traced in this assessment study in the period 2014 through 2018. The enterprises included local cattle; exotic cattle; local goats; exotic goats; pigs of all breeds; local chickens; layer chickens; broiler chickens; kuroiler chickens; and ducks. We also collected data on the livestock inputs received from the program for both the animals, building materials, and veterinary services, including vaccinations and treatments.

Data Analysis and Presentation

The frequency of participation in livestock training was determined as i) a dichotomous question of "yes" or "no" on each module trained in the period 2014 through 2018 based on the seven modules; ii) the estimated number of times trained in each module over the same period. The estimated number of attendance per module was used to generate a three-tier cluster for ease of interpretation. For example, members whose estimates were between one to five times were coded as "one" for "fair" attendance, six to ten times coded as "two" as "good", and above 10 times were coded as "three" as very good attendance. These generated a minimum of "one to seven" and a maximum of "15-21" opportunities for training corresponding to the seven modules. Data on knowledge comprehension and retention were analyzed by grading the six questions where each relatively correct response was assigned one point. Data on livestock production and sales by headcount were analyzed for the total number of livestock kept and/or sold per household for each livestock breed both in 2014 as baseline and 2018 as the endline of the assessment. Headcounts were converted into Tropical Livestock Units (TLUs) that express the carrying capacity of domesticated animals and their stocking rates on the rangeland to their forage consumption, productivity, and greenhouse gas emission (Rothman-Ostrow et al., 2020). Conversions were for every head of cattle=0.7, pigs=0.2, goats and sheep=0.1, and chickens=0.1. Sales revenues were also converted from Ugandan Shillings to United States dollars based on the CSRL/ISU–UP conversion rate in the financial year 2018/2019 budget (i.e., 1US$ 3,400UGX). A bivariant analysis using chi-square was employed to establish if there existed an association between the household biographical characteristics and participation in livestock production in 2014 (baseline), 2018 (endline), dropping out, and (re)joining any livestock enterprises. Data are presented in a tabular form for livestock households by frequencies and percentages.

Results

Assessment of household participation in livestock extension education

Livestock households (47.5%, *n*=174) of 366 participated in the livestock extension education programs during the assessment period between 2014 through 2018. Of the seven livestock training modules assessed in this study, participants attended mostly training on chicken production both local chickens (78.2%) and layer chickens (72.4%) and piggery production (74.7%). The study also found that the majority of the participants (47.7%) participated in at least five of the seven modules. However, there was a low frequency of attendance with the majority of participants (80.5%) attending 1–7 times considered as fair training in the assessment period of 2014 through 2018. In assessing knowledge comprehension and retention, most livestock extension education trainees responded well to questions relating to poultry vaccination (87.4%) and piggery management (70.1%). Table 1. summarizes the assessment.

Table 1

Household Participation in Livestock Extension Education in Kamuli District, Uganda.

Variable	Modules and/or Units of Measure	Frequency	Percentage
Selected livestock modules.	Local chicken production and management	136	78.2
	Piggery production and management	130	74.7
	Layer chicken production and management	126	72.4
	Goat production and management	103	59.2
	Feed formulation and livestock feeding	102	58.6
	Forage production and management	74	42.5
	Livestock marketing and gross margin analysis	74	42.5
Modules attended.	Above average (5–7 modules)	83	47.7
	Average (3–4 modules)	42	24.1
	Below average (1–2 modules)	49	28.2
Frequency of attendance.	Very good (15–21 training)	04	02.3
	Good (8–14 training)	30	17.2
	Fair (1–7 training)	140	80.5
Households who responded correctly to knowledge questions	Why do we vaccinate our birds?	152	87.4
	What are some of the management practices for pigs?	122	70.1
	How many months does a gilt come on heat first time?	109	62.6
	What are some of the litter management practices?	104	59.8
	When does layer chicken start laying?	89	51.1
	How long is the gestation period of a goat?	88	50.6

Influence of Extension Education on Trends in Livestock Production

Livestock households (*n*=366) were asked if they joined and or rejoined [(re)joined] any livestock enterprise and also were asked if they dropped any livestock enterprise from 2014 through 2018. A total of 10 enterprises were traced in this study including local cattle, exotic cattle, local goats, exotic goats, pigs-all breeds, local chickens, layer chickens, broilers, kuroilers, and ducks. The study found that 23.8% of households (re)joined a livestock enterprise and 47.0% dropped a livestock enterprise (see Table 2 for details). The study found a statistically significant association between participating in livestock extension education and dropping out of and/or (re)joining a livestock enterprise. Households who participated in the training were 54.3% more likely to have dropped a livestock enterprise and were, however, 23.0% more likely to have (re)joined a livestock enterprise.

Table 2

Percentage of Households Involved in Livestock Production in Kamuli District, Uganda

Indicators on livestock production: Total number of households who ….	Not Trained (*n*=202)	Trained (*n*=164)	Total (*n*=366)	χ^2
Had any livestock project(s) in 2014	91.6	95.1	93.2	0.130
Had any livestock project(s) in 2018	76.7	75.0	76.0	0.396
(Re)joined livestock projects between 2014–2018	18.8	28.0	23.0	0.025
Dropped out of a livestock project between 2014–2018	41.1	54.3	47.0	0.008

Household Engagement in Livestock Production, 2014 Through 2018

The study found that most households kept local chicken (82.8%), local goats (54.9%), local cattle (44.5%), and pigs (33.6%). The majority of households (75.8%) were found keeping at least two of the 10

livestock breeds tracked in this study. Table 3, provides the details of the livestock kept across the two time periods with households expressed in percentages and livestock heads converted into TLUs and sales.

Table 3

Estimated Household Livestock Production Trends and Sales in Kamuli District, Uganda.

Selected livestock enterprises	Percentage households (*n*=366)	Tropical Livestock Units (TLU)			Estimated total sales revenue ($)	Percentage households sold (*n*=366)
		Available in 2014	Available in 2018	Total sold 2014–2018		
Local chicken	82.8	240.4	217.3	64.3	2,075.9	17.8
Local goats	54.9	59.8	55.8	21.7	4,824.4	16.4
Local cattle	44.5	272.3	176.4	109.9	27,667.6	19.4
Pig-all breeds	33.6	67.4	90.2	32.4	4,202.9	12.6
Ducks	10.4	12.7	11.6	2.8	102.1	2.5
Exotic goats	6.6	6.8	4.1	4.3	2,082.4	2.2
Exotic cattle	4.6	25.2	17.5	11.9	5,088.2	1.6
Layers	2.7	13.0	68.5	48.6	1,227.7	1.6
Kuroilers	1.4	4.4	4.9	1.0	35.3	0.3
Broilers	0.5	11.0	20.0	-	-	-
Totals	**-**	**-**	**-**	**296.9**	**47,306.6**	**45.6**

Increases in Tropical Livestock Units Between 2014 Through 2018

From Table 3, most households were engaged in local chicken, goat, cattle, and piggery production. Overall, it was established that trained households were 44.4% more likely to keep small livestock than 15.6% of non-trained households. Also, layers, piggery, broilers, and kuroilers had an increase in TLUs between 2014 through 2018. Several factors account for the increases in TLUs, especially the 23.0% of the households who (re)joined livestock production. Similarly, CSRL/ISU–UP support in cattle production was visible, especially in veterinary services including vaccination and treatments conducted by Community-Based Animal Health Workers (CBAHWs) (see Table 4). Among the 174 trained livestock households, 60 (34.5%) were "direct" CSRL/ISU–UP input beneficiaries, among whom the majority (53.3%) received piglets. In access to veterinary services, results show that 71.7% of the registered direct CSRL/ISU–UP clients had access. Specifically, 55.0% and 41.7% of the direct clients accessed vaccination and treatments for their livestock respectively through the CBAHWs and program livestock specialists.

Table 4

Percentage Comparison of Livestock Production among Households

Indicator unit	Livestock households (*n*=366)	Participated in training (*n*=174)	Registered member of ISU–UP livestock (*n*=60)
Households with livestock enterprises			
Yes	100	94.3	100
Local chicken	82.8	79.9	85.0
Local goats	54.9	47.1	61.7
Local cattle	44.5	50.0	50.0
Pigs-all breeds	33.6	39.7	53.3
Ducks	10.4	10.9	8.3
Exotic goats	6.6	9.2	16.7
Exotic cattle	4.6	5.2	5.0
Layers	2.7	5.2	15.0
Kuroilers	1.4	2.3	6.7
Broilers	0.5	1.1	-
Households that received livestock inputs			
Yes	12.3	23.0	71.7
Vaccination	9.6	17.2	55.0
Treatment	6.8	14.4	41.7
Forage seeds	4.1	8.0	23.3
Water tank	1.4	2.9	8.3
Building materials	1.4	2.9	8.3
Water pump	0.3	0.6	1.7
Insemination consultations	0.3	0.6	1.7

Decreases in Tropical Livestock Units (TLUs) Between 2014 Through 2018

There was a general reduction in the number of TLUs between 2014 and 2018 for local cattle, local chicken, exotic cattle, local goats, exotic goats, and ducks. Part of the reason for this reduction was the sales made by 45.6% of households, especially sales of local cattle, chicken, and goats (see Table 3.). Also, dropping out of production by 47.0% could partially account for the reduction in TLU. The study found that most households 50.6%, 40.7%, and 35.5% percent dropped out of local chicken, cattle, and goats respectively. The study identified a relationship between sales and dropouts, where enterprises that had the most households in sales had, most of them drop out of production.

Discussions

Assessment of Livestock Extension Education

Participation in extension education on chicken production, both local and exotic/layers, and piggery production had higher attendance. High attendance in layer chicken production training, for instance, could be attributed to their introduction in 2014 among rehabilitated mothers of the nutrition program, youth both in- and out- of school, and their expansion in schools supported by CSRL/ISU–UP to improve school lunch through egg consumption and for income generation through sales of eggs and culls (Masinde, McMillan et al., 2015). Since 2014, beneficiaries of layer chickens, including rehabilitated mothers (Ikendi, Owusu et al., 2023b; 2023c) and schools through school feeding and livestock enterprises (Ikendi, Retallick et al., 2023; Nonnecke et al., 2015) are required to go through rigorous training in all steps of layer chicken management. To foster sustainability in production, beneficiaries are required to do brooding by themselves after the first phase of brooding with the program with ISU–UP providing technical guidance through its livestock specialists and Community-Based Animal Health Workers (CBAHWs).

Layer chickens are labor-intensive and require knowledge at all stages of production that includes organizing the brooder and rearing houses, feed and feed formulation, vaccination schedules, production of eggs, and litter management (Bugeza et al., 2022; Kakooza et al., 2023; MAAIF, 2019).

In piggery, participants gained knowledge on aspects of piggery management including breeding, feeding, treatments, and marketing to improve their efficiency in tapping the available market for pork (Dione et al., 2014; Roesel et al., 2019). Earlier, Kamuli communities were in traditional piggery production until CSRL/VEDCO programs introduced exotic breeds such as Landrace and Camborough in 2005 (Masinde, McMillan et al., 2015). Production continued and was intensified in 2016 under the new ISU–UP leadership with the introduction of crossbreeds. The introduction of crossbreeds was aimed at facilitating production under minimal costs that would be involved with exotic breeds. Research found that genetics and diet do affect weight, quality of carcasses and meat (Kugonza et al., 2015), and reproduction (Babigumira et al., 2023). Additionally, piggery training, especially on the interaction of piggery and humans is paramount for public health. Moreover, in the Kyoga basin where Kamuli district is located, studies revealed widespread *Taenia solium* worm in pigs which affects production (Ngwili et al., 2022; Nsadha et al., 2010; Ouma et al., 2021) and increases epilepsy disease in humans related to eating infected pork (Nsadha et al., 2014). These health issues further necessitated public health education by CSRL/ISU–UP for behavioral change, especially the construction of pit latrines to reduce open defecation which intercepts the lifecycle of *Taenia solium* and improves community public health (Ikendi, Owusu & Masinde, 2023). Other diseases of concern include brucellosis common with the consumption of infected meat and the sharing of water resources with animals (Mugabi et al., 2012; Nguna et al., 2019).

In feeding and feed formulation, participants learn how feeds are formulated based on the purpose of the livestock, breed, age, and the ingredients in their rations. A study by Mwesigwa et al. (2015), for instance, revealed that less than five percent of 300 interviewees in central Uganda knew the ingredients of a nutritive chicken ration. This low knowledge has negative impacts on their productivity since feed formulation and feeding determines the growth rates and feeding costs (Ochieng et al., 2021; Sumbule et al., 2021) much like in piggery production which influences the gross margin from the sales due to efficient production techniques (Adewale et al., 2024). Relatedly, attendance for forage management training was low among participants in this study. Participants in forage management learn the production cycle and management of forages by species. Forages serve multipurpose functions, including both feed for livestock and as a soil conservation tool. In dry seasons, forages are substitutes for scarce natural fodder used in the making of hay and silage (Twinamatsiko et al., 2020), however, low attendance in forage training limits knowledge acquisition and forage adoption in livestock. Maass et al. (2014), for instance, found that the adoption of growing fodder and feeding them to pigs has been slowly adopted as a practice in Uganda, similar results are found in rangeland regions of western Uganda (Twinamatsiko et al., 2020). These challenges are exacerbated by limited sources of forage seeds (Tusiime et al., 2023).

Assessment of Knowledge Comprehension and Retention

In assessing knowledge comprehension and retention, we established that 56.9% of the participants scored at least four of the six possible points in all six knowledge questions (see Table 1). Trainees scored best in areas of reasons why vaccination in poultry is important to keep the flock healthy for better productivity. However, they scored less in the estimation of the gestation period of a goat and when layers start laying. These are key parameters in livestock management, for instance, in determining when to switch the type of feeds like in layers from growers to layers mash (Bugeza et al., 2022; Kakooza et al., 2023; MAAIF, 2019). Knowledge assessment can help depict the possible implementation of lessons learned. Livestock extension advisors are bound to review the methods of delivery during the training to make sure the lessons become learner-centered to influence the grasp of materials. One of the areas to reflect on is the *theory of multiple intelligence* which recognizes that most people have more than one area of intelligence (Gardner, 2010). Employing multiple methods of delivering the materials to create meaningful learning experiences. Employ multiple languages since Kamuli is multilingual, pass the message through music,

engage the learners in discussions, and most importantly employ experiential/hands-on learning and situated learning techniques – learning alongside specialists and model farmers can create have ripple effect on knowledge acquisition. The ISU–UP has emphasized experiential and situated learning in livestock management (see Figure 2) especially piggery at the Mpirigiti Rural Training Center, at the NECs, and in schools with several trainers including global service-learning students pursuing degrees in animal sciences from Iowa State University and Makerere University (Ikendi, Retallick et al., 2023).

Livestock advisors need to bear in mind during training that learning is a process, and adult learners need to use their experiences, thoughts, beliefs, and feelings to construct meaning and effect learning in that process. Adult learners' thinking about learning is different from young learners, and adults need to be heard to contribute to the learning process which also motivates them to continue participating in the training programs (Knowles et al., 2020; Merriam & Baumgartner, 2020; Schunk, 2020). Motivation in learning has a great impact on knowledge comprehension and the application of the lessons learned in such livestock training. Achieving maximum knowledge comprehension requires grouping trainees on a particular module that applies to what they do on their farm. For instance, piggery farmers need to be targeted for piggery training and involved more in practical using their experiences and problem-solving than the traditional theoretical concepts. In doing that, the overall goal of such education is to bring about community empowerment (Dewey, 1938; Freire, 2018) which has a great influence on the adoption of technology and sustaining the adopted technology upon the termination of the agent-client relationship in the change continuum (Rogers, 2003). The CSRL/ISU–UP has worked through this community engagement model, especially with goats where Mubende bucks were introduced to improve the breeding of local goats (Kugonza et al., 2014) and kuroilers and ducks were introduced to improve egg production and hatchability of eggs with such experiments conducted in Kamuli where the technology was later implemented easing adoption (Semahoro et al., 2018).

Influence of Extension Education on Trends in Livestock Production

Overall, 23% of livestock households (re)joined a livestock enterprise. This study also found that households who participated in the livestock extension education programs were 28% more likely to (re)join a livestock enterprise than 18.8% of non-trained households. The knowledge acquired from livestock training programs is influential in initiating enterprises and influencing the adoption of livestock innovations like in goat, piggery, kuroilers, and duck production. According to the change continuum (Rogers, 2003), this impact is the essence of the extension system playing the role of influencing change and adoption of innovations in the communities. Similarly, education according to early progressive movement philosophers is meant to bring about empowerment to drive fundamental change in communities (Dewey, 1938; Freire, 2018). In addition to households who (re)joined, we found that 23.0% of trained households received livestock services and input from the CSRL/ISU–UP (see Table 4). The inputs included livestock treatments, vaccinations, building materials, forage seeds, water tanks, layers, breeding bucks, kuroilers, and ducks. The provision of inputs and services is partly a call by earlier studies in the program (Ampaire & Rothchild, 2011) that training alone is not enough to uplift the status of livestock households, farmers require additional input support. Farmers who (re)joined were 79.8% more likely to spend less than 30 minutes from primary water sources, which suggests that support provided by the program in the form of livestock water tanks contributed to having water sources within the vicinity of the households. The reduced time taken to fetch water for livestock enabled farmers to engage in other production activities including crop irrigation using water from the livestock water tanks as stated in the agronomy extension study by Ikendi, Owusu et al. (2024b) within this same population.

Household Engagement in Livestock Production, 2014 Through 2018

On production, overall, 366 (80.6%) households were involved in livestock, a proportion higher than that established for the entire Kamuli district in the national livestock censuses of 2014 with 65.7% (UBOS, 2017) and 2021 with 72.7% (UBOS, 2024). These statistics depict the culture of rearing animals

in the Kamuli district which makes it easier for development organizations like CSRL/ISU–UP and its livestock partners such as the International Livestock Research Institute [ILRI] and Heifer Project International (see Figure 2) to diffuse innovations to improve the productivity of the local herds starting with their indigenous knowledge (Ikendi & Retallick, 2023b; Masinde & McMillan, 2015). Households kept mostly local chickens, goats, and cattle; a statistic similar to that of the 2021 national livestock census for Kamuli district (UBOS, 2024). Most trained households (44.4%) kept small livestock, a finding similar to earlier studies and the influence of the CSRL/VEDCO program. Earlier studies in CSRL-supported livestock households indicate that small livestock is easy to sell off and/or slaughter for household consumption (Ampaire & Rothchild, 2010a; Natukunda et al., 2011a; 2011b; Masinde, McMillan et al., 2015; Walugembe et al., 2014). Moreover, within this study population, we found that livestock households were more food secure (Ikendi Owusu et al., 2023a), with good dietary scores (Ikendi, Owusu et al., 2024a), and health mothers and children of 0–59 months of age (Ikendi, Owusu et al., 2023b). Studies affirm that with other livelihood programs, livestock improves food security (Bain et al., 2020; Kalinaki, 2025).

The study also noted an increase in tropical livestock units (TLU) between 2014 through 2018, especially among layer chickens, piggery, and kuroilers. Several factors account for these increases in TLUs especially among the households who (re)joined livestock enterprises. In 2014, the CSRL/ISU–UP partnership invested in layer chickens among mothers in the nutrition program, youth in the entrepreneurship program, and schools in their school livestock to supplement eggs in school lunches and overall to raise income through sale of eggs and culls (Masinde, McMillan et al., 2015; Ikendi, Owusu et al., 2023b; Nonnecke et al., 2015; Byaruhanga, 2016). The livestock project was expanded to include local chicken, piggery, goats, and kuroilers. These livestock species are mainly categorized as small livestock that farmers can easily manage given the land shrinkage in their communities and the low access to water and feeding (Ikendi, Owusu et al., 2024b). Small livestock like piggery, goats, and chickens are gender aligned towards women farmers (Ampaire & Rothchild, 2011; Babigumira et al., 2019; Dione et al., 2014; Enahoro et al., 2021; Okot et al., 2018) who are actively involved in CSRL/ISU–UP livelihoods programs to improve their household food, nutrition and income security (Ikendi, Owusu et al., 2023c).

In addition to livestock training and livestock breeds, CSRL/ISU–UP supports households with materials including water tanks, forage seeds, and veterinary services such as vaccination and treatment of animals (see Table 4). Under philanthropic support, CSRL/ISU–UP operates under the United States and the Iowa State University land grant philosophy which embeds the values of teaching, research, and extension (Ikendi & Retallick, 2023b) and is also in line with the university's mission of making Iowa and the world a better place through teaching, research, extension, and service (Iowa State University, 2022, p. 3). The program adopts innovative livestock interventions based on scientific research (Acker et al., 2015; Ikendi & Retallick, 2023a; 2023b) while engaging local communities to harness indigenous knowledge (Masinde & McMillan, 2023; Ikendi & Retallick, 2023b), a strong factor in influencing the adoption of innovations (Rogers, 2003). Several livestock innovations, for instance, pig weight estimation using body indices (Semakula et al., 2011; Walugembe et al., 2014) and mobile scales (Marshall et al., 2023) have been promoted among households. These studies identified that farmers in the Kamuli district were cheated by middlemen while valuing their live pigs based on weight estimation by looking at the animals with naked eyes. Similarly, Mubende bucks/goats, due to their resistance and good breeding efficiency were introduced among Kamuli district farmers to improve the breeding of local goats (Kugonza et al., 2014). Also, local chickens have been promoted to crossbreed with kuroilers and using ducks to improve hatchability all related to the findings of Semahoro et al. (2018) in Kamuli and other districts where they conducted experimental studies. Other earlier studies included Natukunda et al. (2011a; 2011b) on the potential of local chicken to revitalize farmers' consumption of animal source proteins and incomes from sales; and the extensive piggery production studies conducted by IRLI, a partner with the CSRL/ISU–UP in livestock improvements in Kamuli district Uganda (Dione et al., 2014; Ouma et al., 2014; 2015; Roesel et al., 2019).

The study also noticed a general reduction in the number of tropical livestock units (TLUs) between 2014 and 2018, especially for local cattle, local chicken, exotic cattle, local goats, exotic goats, and ducks. This reduction could be partially a result of the sales made by 45.6% of households (see Table 3). Most households made sales of local cattle, chickens, and goats, confirming the claim that small livestock like goats and chickens can easily be liquidated to meet household demand (Okot et al., 2018; Ampaire & Rothchild, 2010a; Masinde et al., 2015a; Walugembe et al., 2014). Also, households who dropped out of production for at least one livestock enterprise were 47.0%, this partially accounts for the reduction in TLUs. Most households dropped out of local chicken, cattle, and goats. The study established a relationship between total sales and households dropping out of production. Livestock enterprises that had the most households with sales, these households had the most drop-out of production in those particular enterprises. Similarly, home consumption, exchanges (e.g., goats for cattle, chickens for goats), payment of dowry with livestock; death due to pests and diseases, and losses through theft and wild animals could have contributed to a reduction. Payment of dowry with livestock, specifically cows, goats, and roosters/cocks is a tradition in the Uganda family setting (Waiswa et al., 2021).

Related to sales, overall, 45.6% of livestock households made sales between 2014 through 2018. Although most of the sales and revenue were from cattle, CSRL/ISU–UP focuses on small livestock given the nature of the households that the program and the livestock integration program support, who have limited resources. Nevertheless, layer chickens had higher mean revenue (see Table 3.) probably due to the sale of off layers (culls) in preparation for restocking among households especially those supported by CSRL/ISU–UP (Ikendi, Owusu et al., 2023c). The study established that 75.5 TLUs related to layers chickens were program support which accounts for the majority and before 2014, only 11.0 TLUs were established in layers chickens. Similarly, pigs, goats, and local chickens were more easily sold than large animals, a finding consistent with earlier findings in the program (Ampaire & Rothchild, 20110a). However, the greatest challenge was the low unit price despite the readily available market. Piggery, for instance, has a ready market in Uganda (Roesel et al., 2019), however, research established that pigs raised on a small scale in Africa have low average weight (Dione et al., 2014; Nsadha et al., 2014; Walugembe et al., 2014). This low weight was a function of many factors including diseases, pests, lack of shelter, feeding, and poor breeding habits of mating sows and gilts with any available boar Different studies on rural livestock have accounted for the low prices as a function of a lack of market information (Maass et al., 2014; Natukunda et al., 2011b). Similarly, the selling method was based on the farmer's bargaining power, poor live weight estimation by eyesight causes middlemen to exploit the farmers (Ampaire & Rothchild, 2010a; Lubandi et al., 2019). This method of price estimation suggests a better approach to weight estimation (Marshall et al., 2023; Walugembe et al., 2014) coupled with proper sanitation, feeding, and breeding to improve carcass quality in all livestock enterprises.

Conclusions

The livestock integration programs of the Center for Sustainable Rural Livelihoods (CSRL)/Iowa State University Uganda Program (ISU–UP) are designed to empower the capacity of livestock households in sustainable production and management of livestock enterprises to increase their productivity. The study assessed the influence of livestock extension education and intervention programs towards the adoption of sustainable livestock production and management practices for improving household livelihoods in the Kamuli district, Uganda. We compared the households who participated in the livestock training and those who never trained in the period 2014 through 2018. This period was commensurate with the CSRL/ISU–UP impact evaluation of the 2015/2019 strategic plan, the first phase of the CSRL/ISU–UP partnership. Overall, the study established that 80.6% of the households in the Kamuli district are livestock farmers, among whom 47.5% participated in livestock training programs. The majority of livestock households trained in modules related to local chickens, layer chickens, piggery, goat production, and feeding and feed formulation, but less in forage production, marketing, and gross margin analysis. The study found that households who participated in the training programs were more likely to be involved in livestock

production, suggesting a need for continued training programs. The study also identified that 23.0% of the households (re)joined at least a livestock enterprise and those who (re)joined were influenced by participation in livestock training programs. Some of the participants received livestock inputs from the CSRL/ISU–UP such as chicks, feeds, and livestock water tanks reducing the time spent to fetch water for their livestock, domestic use, and crop irrigation. However, we also identified that 47.0% of households dropped out of at least a livestock enterprise and were associated with high livestock sales and fewer household items like mobile phones, bicycles, and radios that could be used by farmers.

Kamuli district, Uganda is a livestock farming community with 80.6% of households involved in livestock production enterprises. These results show a culture of rearing animals, becoming easier for development organizations to diffuse innovations to improve the productivity of the local herds starting with the farmers' lived experiences and their indigenous knowledge. The CSRL/ISU–UP livestock integration program introduced into the community improved breeds of livestock including kuroilers and ducks to improve egg production and hatchability, layer chickens, Mubende bucks/goats for breeding, and pigs for their prolific production. In livestock feeding, the program introduced forage for farmers to grow and feed their livestock to supplement local grasses. The success of diffusion of such technologies required a down-to-earth approach, working directly with livestock farmers through Community-Based Animal Health Workers (CBAHWs) and livestock specialists to influence farmers to buy-in the new livestock breeds and innovations in breeding programs, a strategy in line with the change continuum concept (Rogers, 2003). For instance, the program opted to improve the productivity of the existing local goats in breeding programs using the Mubende bucks/goats because of their productivity. Similarly, the program introduced kuroilers to improve egg and meat production, and ducks to improve the hatchability of kuroilers' eggs after several experiments in Kamuli and other districts in Uganda (Semahoro et al., 2018). Layer chickens targeted improving the nutrition of mothers and children after discharge from at-risk-for-malnutrition rehabilitation centers, and in schools to improve the nutrition of school lunches, and among out-of-school youth to improve their finances and nutrition. The CSRL/ISU–UP capitalizes on scientific research that reinforces the ISU land grant ethos abroad (Acker et al., 2015; Ikendi & Retallick, 2023a; 2023b; ISU, 2022) and also relies on indigenous knowledge by understanding the customs in their livestock management paramount for the success of these innovations (Ikendi & Retallick, 2023b; Masinde, & McMillan., 2015). Indigenous knowledge has an element of wisdom and grows with experience in production.

Implications and Recommendations

Livestock extension advisors as change agents build on existing local experiences coupled with scientific research to strengthen and influence change from traditional to improved and sustainable livestock production and management practices to enhance the productivity of farmers' livestock enterprises. It is the role of the livestock advisors as change agents, with partner organizations to carry out the needs assessments, in a participatory and culturally responsive approach, evaluating the intended innovation programs, and providing alternative options before the implementation (Hood et al., 2015). Change agents need to prepare the communities to carry on the livestock programs once they succeed in ensuring continuity and sustainability. This study identified that building the human capacity of livestock households can improve livestock production and management and also influence behavioral changes to make informed livestock production decisions. Additionally, understanding the norms of the social system of a community and integrating indigenous knowledge in the innovations are key facets for the success of livestock programs especially those that are aimed at improving the productivity of local stock compared to introducing new breeds and innovations. The study identified that this strategy was adopted by CSRL/ISU–UP and uses CBAHWs as change agents. These CBAHWs are natives of the communities whose impact influences the level of participation of households in the training programs and adoption of livestock techniques similar to what they practice on their farms as community-based educators. Their role as change agents in the change continuum (Rogers, 2003) also supports the concept of subjective norms in the theory of planned behavior (Ajzen, 2020), relating to the support livestock farmers get from peers and advisors.

In influencing technology transfer and the adoption of innovations in livestock production, we consider the following aspects as important to the steps followed in the change agents' continuum (Rogers, 2003). Innovative technology must be appropriate and be sociable with the needs of the recipients to support their sustainable development, for instance, the adoption of Mubende buck/goats to improve the breeding efficiency of local goats. In such innovations, learning must be at the center of the technology transfer process to meet the educational criteria for community empowerment. Also, building the capacity of livestock farmers helps to achieve continuity of livestock programs after the termination of the relationship with change agents and organizations. Additionally, the extension education process which comprises the needs assessment, program development, delivery systems, learning system, and evaluation must support the transfer of technology. Because technology is a product of continuous learning through research and discovery, livestock programs need to rely on scientific research blended with indigenous knowledge to influence the adoption of innovative production techniques.

The transfer of technology processes must be grounded in the education processes and must be accessible to all. We found that CSRL/ISU–UP allowed community households to attend the livestock training programs irrespective of their affiliation or registration with the program. However, we found some training programs with low attendance like forage production and use, similar to other studies which hamper the adoption of such production practices, yet they are alternatives to natural fodder (Tusiime et al., 2023; Twinamatsiko et al., 2020). This study also finds it important to emphasize the needs of adult learners, the learning process, and what motivates them to learn during the training (Knowles et al., 2020; Merriam & Baumgartner, 2020; Schunk, 2020). There is a need to adopt active participation strategies in the learning process to influence knowledge acquisition and retention (Gardner, 2010). Active learning also influences the post-learning assessment grades, which are vital in improving the delivery of training programs. Active adult participation coupled with hands-on activities helps adults share their experiences. It is also an important motivator to adult learning and knowledge comprehension and retention which helps in implementing the lessons learned, and outcome evaluation for program improvements.

The application of any innovative technology requires an evaluation of impact. The case of this study was an impact evaluation of the first strategic plan activities of the 2014/2019 first phase of the CSRL/ISU–UP partnership toward food security, nutrition security, and public health through livelihood programs including livestock integration. While the impact evaluation showed a positive contribution of livestock to food security and nutrition security, it was prudent to identify the details of this livestock program that we have uncovered in this article. Change agents and their organizations need to understand that new technologies may not always be the most appropriate for every situation, however, evaluating them gives a sign about the next phase of action for program improvement. This study advocates continuing studies to assess the impact of livestock education programs periodically to understand the level of knowledge comprehension and adoption of innovations and adaptation stages (Rogers, 2003). Also seeking feedback from livestock farmers on pertinent issues affecting their decision to drop out and/or (re)join various livestock enterprises. The feedback from continuous assessment helps determine what component of the change continuum requires more effort. Feedback can also help determine the components of the theory of change that ground the operations of the CSRL program (Sseguya & McMillan, 2015) are taken care of, to achieve the ultimate goal of food and nutrition security and financial stability of the households.

To ascertain the gross margin, further studies are recommended to establish the total revenue from the products such as eggs, manure from kraals and poultry after culling, and milk sales. Similarly, estimate expenses of the farmers in the cost of production for different cost centers including feeding, vaccines, treatments, and transportation. The authenticity of these analyses will be a function of record-keeping which resonates with the ability of livestock extension education agents to train farmers in keeping production records as a norm. In sum, the study recommendations are on broadening the training of farmers beyond current production and management assessed in this study to include topics on emerging threats of climate change on livestock productivity (Nampijja et al., 2025); advancements in technology including artificial

insemination to manage adverse issues related to inbreeding (Ali et al., 2024; Businge et al., 2025). In feeding, training is required on new feeding programs for poultry such as substitution of black soldier fly larvae meal to reduce costs associated with feed meal (Nampijja et al., 2023). Dissemination of research findings on breeding programs both in large animals (Masaba et al., 2024) and small animals (Beyihayo et al., 2023; Kayondo et al., 2023; Yussif et al., 2023) that could potentially influence the uptake of new technologies as they become available, maintaining the program's ethos of advancing livestock programmatic approaches based on research and indigenous knowledge. Current studies are being conducted in piggery-related stress, its coping mechanism, and the potential selection for breeding (Deckers et al., 20025; Kayondo et al., 2023; 2024; 2025), however, the success of such innovative ideas rests in the ability of extension advisors to disseminate the technologies through education to influence adoption. Upgrading of service providers and establishment of resource centers for both farmers and advisors to keep up with the pace of livestock development. Engaging policy makers on policies on training and capacity building efforts. Also, intensifying support to farmers who relapse back into poverty after livestock initiatives collapse or drop out of production, which requires continued public-private partnerships.

References

Acker, D. G., Musoke, H. K., & Sseguya, H. (2015). Capitalizing on impacts & 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.

Adewale, C. I., Munezero, E., Ndyomugyenyi, E. K., & Mugonola, B. (2024). Comparative analysis of profitability drivers of pig production systems in Northern Uganda. *Journal of Sustainable Agriculture*, *39*(2), 370–380. http://dx.doi.org/10.20961/carakatani.v39i2.79786

African Union. (2015). *Agenda 2063: The Africa we want.* https://au.int/en/agenda2063/overview

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

Ali, S., Dire, M., Degefa, T., Funga, A., Jemal, H., Regassa, G., & Youngs, C. R. (2024). Dairy village: The role of veterinary services in unlocking dairy industry potential through assisted reproductive technologies. *Ethiopian Veterinary Journal*, *28*(1), 1−14. https://doi.org/10.4314/evj.v28i1.1

American Association for Agricultural Education (AAAE). (2023). *AAAE research values*. Retried from: https://aaea.wildapricot.org/National-Research-Values

Ampaire, A., & Rothschild, M. F. (2010a). Effects of training and facilitation of farmers in Uganda on livestock development. *Livestock Research for Rural Development, 22,* Article #130. http://www.lrrd.org/lrrd22/7/ampa22130.htm

Ampaire, A., & Rothschild, M. F. (2010b). Pigs, goats, and chickens for rural development: smallholder farmer's experience in Uganda. *Livestock Research for Rural Development, 22,* Article #102. http://www.lrrd.org/lrrd22/6/ampa22102.htm

Ampaire, A., & Rothschild, M. F. (2011). Differences between men and women farmers' experiences with a livestock development program in Kamuli, Uganda. *Livestock Research for Rural Development, 23,* 38. http://www.lrrd.org/lrrd23/2/ampa23038.htm

Babigumira, B. M., Sölkner, J., Mészáros, G., Wurzinger, M., Pfeiffer, C., Lewis, C. R., ... & Marshall, K. (2023). The effect of the proportion of Modern European ancestry on grower and sow performance of pigs in smallholder systems in Uganda. *Frontiers in Genetics*, *14*, 1123826. https://doi.org/10.3389/fgene.2023.1123826

Bain, C., Ransom, E., & Halimatusa'diyah, I. (2020). Dairy livestock interventions for food security in Uganda: What are the implications for women's empowerment? *Rural Sociology*, *85*(4), 991–1020. https://doi.org/10.1111/ruso.12332

Beyihayo, G. A., Kugonza, D. R., Ndyomugyenyi, E. K., Echodu, R., Okot, M. W., & Anjos, F. D. (2023). Genetic and phenotypic parameter estimates for selection within Ugandan indigenous chickens. *Animal Health and Production*, *55*(2), 100. https://doi.org/10.1007/s112-023-03513-7

Bell, L. W., Moore, A. D., & Thomas, D. T. (2021). Diversified crop-livestock farms are risk-efficient in the face of price and production variability. *Agricultural Systems*, *189*, 103050. https://doi.org/10.1016/j.agsy.2021.103050

Bugeza, J., Mutagubya, F., Ssekamanje, R., Mulondo, H., Asiimwe, T., Mbaziira, A., ... & Ayebazibwe, C. (2022). *Reconnaissance of major challenges affecting poultry farming using participatory epidemiology methods in Jinja District, Uganda*. RUFORUM working document 20.

Businge, M., Kugonza, D., Kasoro, I., Ouma, E., & Marshall, K. (2025). *Adoption of pig Artificial Insemination by pig keepers in Uganda through SAPLING supported artificial insemination service providers*. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/168915

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.

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]. Repository. http://ir-library.ku.ac.ke/handle/123456789/17759

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

Dekkers, J. C. M., Delpuech, E., Cheng, J., Kayondo, F., & Riquet, J. (2025, January 10–15). *Gene set enrichment analysis of GWAS results from Bayesian Variable Selection Methods* (Presentation). PAG32 conference. San Diego, California.

Dewey, J. (1938). *Experience and education*. Touchstone.

Dione, M. M., Ouma, E. A., Roesel, K., Kungu, J., Lule, P., & Pezo, D. (2014). Participatory assessment of animal health and husbandry practices in smallholder pig production systems in three high poverty districts in Uganda. *Preventive Veterinary Medicine*, *117*(3–4), 565–576. https://doi.org/10.1016/j.prevetmed.2014.10.012

Enahoro, D., Galiè, A., Abukari, Y., Chiwanga, G. H., Kelly, T. R., Kahamba, J., ... & Ouma, E. (2021). Strategies to upgrade animal health delivery in village poultry systems: Perspectives of stakeholders from northern Ghana and central zones in Tanzania. *Frontiers in Veterinary Science*, *8*, 611357. https://doi.org/10.3389/fvets.2021.611357

Flax, V. L., Ouma, E. A., Baltenweck, I., Omosa, E., Girard, A. W., Jensen, N., & Dominguez-Salas, P. (2023). Pathways from livestock to improved human nutrition: Lessons learned in East Africa. *Food Security*, *15*(5), 1293−1312. https://doi.org/10.1007/s12571-023-01382-4

Food and Agriculture Organization (FAO). (2017). *Africa sustainable livestock 2050*. Rome: Italy.

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

Gardner, H. (2010). *Multiple intelligences: The theory in practice*. Basic Books.

Hood, S., Hopson, R. K., & Kirkhart, K. E. (2015). Culturally responsive evaluation. Theory, practice, and future implications. In K. Newcomer, H. Hatry and J. Wholey, (Eds.), *Handbook of practical program evaluation* (pp. 281–317). John Wiley & Sons.

Ikendi, S., & Retallick, M. (2023a, May 15−18). *Improving managerial and leadership effectiveness in multistakeholder organizations* (Proceedings, pp. 636−655). National American Association for Agricultural Education Conference. Raleigh: North Carolina, United States.

Ikendi, S., & Retallick, M. (2023b, 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). Association for International Agricultural and Extension Education Conference. Guelph: Canada.

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

Ikendi, S., Owusu, F., & Masinde, D. (2023, May 15−18). *Community education for behavioral change towards food and nutrition security* (Poster proceedings, pp. 395−398). National AAAE Conference. Raleigh: NC. https://www.researchgate.net/publication/371255846

Ikendi, S., Owusu, F., Masinde, D., Oberhauser., & Bain, C. (2024a, April 22–25). *Improving household dietary diversity and caloric intake through livelihood education interventions in Eastern Uganda* (pp. 689–695). AIAEE: Orlando, Florida. https://www.researchgate.net/publication/381092961

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2024b). Assessment of agronomy, agroforestry, orchards, grain storage, and postharvest education programs on empowerment of farmers in rural Uganda. *Journal of Agricultural Education, 65*(1), 99–125. https://doi.org/10.5032/jae.v65i1.98

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2023a). 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. (2023b 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.

Ikendi, S., Owusu, F., Masinde, D., Oberhauser, A., & Bain, C. (2023c). 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

Iowa State University, (2022). *A dynamic, innovative journey: 2022–2031 strategic plan*. Ames, Iowa. https://strategicplan.iastate.edu/wp-content/themes/strategic-plan/pdfs/StrategicPlan.pdf

Kakooza, S., Eneku, W., Ayebare, D., Ndoboli. D, Mbatidde, I., Waiswa, J., … & Moodley, A. (2023). *Training manual for frontline animal extension service providers on antimicrobial resistance in poultry production*. Ministry of Agriculture, Animal Industry and Fisheries. Kampala: Uganda.

Kakungulu, B., Mwenyi, R. M., Ikendi, S., Natwijuka, M., Arinda, A., ..., & Ahabwe, A. (2025, April 14–17). *Harnessing gender roles in the dairy value chain to improve productivity in the southwestern milkshed of Uganda* (Poster). AIAEE Annual Conference. Inverness: Scotland.

Kayondo, F., Al-Shanoon, H., Seddon, Y., Carette, D., Cole, C., Janz, D., ... & Dekkers, J. C. (2023). Genetics of stress hormone concentrations in hair of healthy nursery pigs and their relationship with back test responses. *Animal Science*, *101*(3), 29–30. https://doi.org/10.1093/jas/skad281.036

Kayondo, F., Al-Shanoon, H., Seddon, Y., Carette, D., Cole, C., Janz, D., ... & Dekkers, J. C. (2025a, January 10–15). *Stress hormones in hair as genetic indicators of stress response and disease resilience in pigs* (Presentation). PAG32 conference 2025: San Diego, CA.

Kayondo, F., Al-Shanoon, H., Seddon, Y., Carette, D., Cole, C., Janz, D., ... & Dekkers, J. C. (2025b, January 10–15). *A genome-wide association study of measures of stress response in young healthy pigs and in grow-to-finish pigs exposed to a natural polymicrobial disease challenge* (Poster). PAG32 conference: San Diego, California.

Kayondo, F., Al-Shanoon, H., Seddon, Y., Carette, D., Cole, C., Janz, D., ... & Dekkers, J. C. (2024, November 5–7). *Genetic relationships of measures of response to non-infectious stress in young healthy pigs with resilience to disease in a natural polymicrobial disease challenge* (Poster). NSIF Annual Meeting. Nashville, Tennessee.

Kalinaki, H. (2025). *Impact of household food security and anaemia on pregnancy outcomes among rural women in Eastern Uganda* (Thesis, Institut Pertanian Bogor). Repository. https://gizi-fema.ipb.ac.id/wp-content/uploads/2025/01/Kalinaki-Hanifar_Promdok_I1604222801.pdf

Knowles, M. S., Holton III, E. F., Swanson, R. A., & Robinson, P. A. (2020). *The adult learner: The definitive classic in adult education and human resource development.* Routledge.

Kugonza, D. R., Lubandi, C., Kirembe, G., Taabu, H. L., & Lusembo, P. (2015). Effect of genotype and post-weaning diet in enhancing pig production within Lake Victoria crescent in Uganda. *TCA and Rural Cooperation, 4,* 3, 296–304 https://ruforum.wordpress.com/wp-uploads/2015/03/cta203

Kugonza, D. R., Stalder, K. J., & Rothschild, M. F. (2014). Effects of buck and doe size on the growth performance and survival of their progeny. *Livestock Research for Rural Development, 26*(3), Article 47. http://www.lrrd.org/lrrd26/3/kugo26047.html

Leyland, T., Lotira, R., Abebe, D., Bekele, G., & Catley A. (2014). *Community-based animal health workers in the horn of Africa: An evaluation for the US Office for Foreign Disaster Assistance*. Feinstein International Center, Tufts University Africa Regional Office, Addis Ababa. https://fic.tufts.edu/wp-content/uploads/TUFTS_1423_animal_health_workers_V3online.pdf

Lubandi, C., Lwasa, S., Kugonza, D., Brian, B. M., Nadiope, G., & Okot, M. W. (2019). Analysis of indigenous chicken value chain in Uganda. *African Journal of Rural Development*, *3*(3), 895–912. https://www.afjrd.org/jos/index.php/afjrd/article/view/277/161

Maass, B. L., Kabirizi, J. M., Pezo, D. A., Carter, N., Ouma, E. A., Zziwa, E., & Chiuri, W. L. (2014, September 17–19). *Opportunities for feeding forages to pigs in Uganda: Bridging the gap between increasing knowledge and decreasing resources* (Poster). Tropentag Conference. Prague.

Machebe, N. S., Ikeh, N. E., Uzochukwu, I. E., & Baiyeri, P. K. (2023). Livestock—crop interaction for sustainability of agriculture and environment. In M. Farooq, N. Gogoi, and M. Pisante, (Eds.), Sustainability a*griculture and the environment* (pp. 339–394). Academic Press.

Marshall, K., Poole, J., Oyieng, E., Ouma, E., & Kugonza, D. R. (2023). A farmer-friendly tool for estimation of weights of pigs kept by smallholder farmers in Uganda. *Tropical Animal Health and Production*, *55*(3), 219. https://doi.org/10.1007/s11250-023-03561-z

Masaba, J. K., Babigumira, B. M., Kugonza, D. R., & Mpairwe, D. (2024). The Zenga cattle of Uganda: Insights from morphometric measurements. *Emerging Animal Species*, *10*, 100040. https://doi.org/10.1016/j.eas.2023.100040

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.

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.

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.

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

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

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), (2019). *Poultry training manual for extension workers in Uganda*. Entebbe, Uganda.

Mugabi, R., Khaitsa, M. L., Miller, R. A., Nakavuma, J. L., Ssajjakambwe, P., Kaneene, J. B., & Barigye, R. (2012). Seroprevalence of brucellosis in selected herds of cattle and goats in Kiruhura district, Uganda. *The African Journal of Animal & Biomedical Sciences*, *7*(2), 28–30.

Mwesigwa, M., Semakula, J., Lusembo, P., Ssenyonjo, J., Isabirye, R., Lumu, R., & Namirimu, T. (2015). Smallholder local chicken production and available feed resources in central Uganda. *Journal of Agricultural Sciences*, *16*(1), 107–113. http://doi.org/10.4314/ujas.v16i1.9

Nabwiire, L., Shaw, A., Nonnecke, G., Talbert, J., Muyanja, C., Boylston, T., Tarté. R., & Prusa, K. (2023). Compliance with food safety standards by beef vendors at butcheries in Kamuli district, Uganda. *African Journal of Food Science, 17*(9), 192−206. https://AJFS/article-pdf/3225271169

Nampijja, Z., Walusimbi, S. S., Zziwa, E., Kugonza, D. R., Kiggundu, M., Kamatara, K., ... & Nakakaawa, C. J. (2025). Impact of rising temperatures on scavenging chicken production in Uganda: Farmer perceptions, challenges and coping strategies. *Tropical Animal Health and Production*, *57*(2), 97. https://doi.org/10.1007/s11250-025-04333-7

Nampijja, Z., Kiggundu, M., Kigozi, A., Lugya, A., Magala, H., Ssepuuya, G., ... & Mugerwa, S. (2023). Optimal substitution of black soldier fly larvae for fish in broiler chicken diets. *Scientific African*, *20*, e01636. https://doi.org/10.1016/j.sciaf.2023.e01636

Natukunda, K., Kugonza, D. R., & Kyarisiima, C. C. (2011a). Indigenous chickens of the Kamuli Plains in Uganda: I. Production system and flock dynamics. *Livestock Research for Rural Development*, *23*(10), Article 220. http://www.lrrd.org/lrrd23/10/natu23220.htm

Natukunda, K., Kugonza, D. R., & Kyarisiima, C. C. (2011b). Indigenous chickens of the Kamuli Plains in Uganda: II. Factors affecting their marketing and profitability. *Livestock Research for Rural Development*, *23*(10), Article 221. http://www.lrrd.org/lrrd23/10/natu23221.htm

Nguna, J., Dione, M., Apamaku, M., Majalija, S., Mugizi, D. R., Odoch, T., … & Graham, T. (2019). Seroprevalence of brucellosis and risk factors associated with its seropositivity in cattle, goats and humans in Iganga District, Uganda. *The Pan African Medical Journal*, *33*, 99. https://doi.org/10.11604/pamj.2019.33.99.16960

Ngwili, N., Thomas, L., Githigia, S., Johnson, N., Wahome, R., & Roesel, K. (2022). Stakeholders' knowledge, attitude, and perceptions on the control of *Taenia solium* in Kamuli and Hoima Districts, Uganda. *Veterinary Science*, *9*, 833721. https://doi.org/10.3389/fvets.2022.833721

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.

Nsadha, Z., Saimo, M., Waiswa, C., Ojok, L., Willingham, A. L., Mutagwanya, R., ... & Lubega, G. W. (2010). Risk factors and lingual prevalence of porcine cysticercosis in the Lake Kyoga Basin in Uganda. *Africa Journal of Animal and Biomedical Sciences 5*(3), 43−50. https://erepository.uonbi.ac.ke/handle/11295/9805

Nsadha, Z., Thomas, L. F., Fèvre, E. M., Nasinyama, G., Ojok, L., & Waiswa, C. (2014). Prevalence of porcine cysticercosis in the Lake Kyoga Basin, Uganda. *BMC Veterinary Research*, *10*(239). https://doi.org/10.1186/s12917-014-0239-y

Ochieng, P. E., Scippo, M. L., Kemboi, D. C., Croubels, S., Okoth, S., Kang'ethe, E. K., ... & Antonissen, G. (2021). Mycotoxins in poultry feed and feed ingredients from Sub-Saharan Africa and their impact on the production of broiler and layer chickens: A review. *Toxins*, *13*(9), 633. https://doi.org/10.3390/toxins13090633

Okello, D. M., Akite, I., Atube, F., Kalule, S. W., & Ongeng, D. (2023). Examining the relationship between farmers' characteristics and access to agricultural extension. *The Journal of Agricultural Education and Extension*, *29*(4), 439–461. https://doi.org/10.1080/1389224X.2022.2082500

Okot, M. W., Mugonola, B., Aryemo, I. P., Kule, E. K., Kugonza, D. R., & Akite, I. (2018). Gender dimensions in the local chicken value chain in northern Uganda. *Journal of Science, Technology, Innovation and Development*, *10*(3), 367−380. https://hdl.handle.net/10520/EJC-fa3ce0868

Ouma, E., Dione, M., Lule, P., Pezo, D., Marshall, K., Roesel, K., … & Jagwe, J. (2015). *Smallholder pig value chain assessment in Uganda: Results from producer focus group discussions and key informant interviews*. Nairobi, Kenya: ILRI.

Ouma, E., Dione, M., Lule, P., Roesel, K., & Pezo, D. (2014). Characterization of smallholder pig production systems in Uganda: Constraints and opportunities for engaging with market systems. *Livestock Research for Rural Development 26,* Article #56. http://www.lrrd.org/lrrd26/3/ouma26056.htm

Ouma, E., Dione, M., Mtimet, N., Lule, P., Colston, A., Adediran, S., & Grace, D. (2021). Demand for *Taenia solium* cysticercosis vaccine: Lessons and insights from the pig production and trading nodes of the Uganda pig value chain. *Frontiers in Veterinary Science*, *8*, 611166. https://doi.org/10.3389/fvets.2021.611166

Ouma, E. , Mugabi, D., Ssimbwa, D., Kugonza, D. R., Hasahya, E. Sserwadda, J. … & Nsadha, Z. (2024). *Pig farmers knowledge enhanced through pig smart extension platform in Uganda*. Nairobi, Kenya. ILRI. https://hdl.handle.net/10568/168983

Owen, E., Kitalyi, A., Smith, T., & Jayasuriya, N. (Eds.). (2020). *Livestock and wealth creation: Improving the husbandry of animals kept by resource-poor people in developing countries*. Nottingham University Press.

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.

Roesel, K., Ejobi, F., Dione, M., Pezo, D., Ouma, E., Kungu, J., ... & Grace, D. (2019). Knowledge, attitudes and practices of pork consumers in Uganda. *Global Food Security*, *20*, 26–36. https://doi.org/10.1016/j.gfs.2018.12.001

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

Rothman-Ostrow, P., Gilbert, W., & Rushton, J. (2020). Tropical livestock units: Re-evaluating a methodology. *Frontiers in Veterinary Science*, *7,* 556788 https://doi.org/10.3389/fvets.2020.556788

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

Semahoro, F., Kugonza, D., Babigumira, B. M., Walusimbi, S., Nadiope, G., & Okot, M. W. (2018). *Growth performance of chicken genotypes based on indigenous populations of Eastern Uganda* (Proceedings, p. 557). World Congress on Genetics Applied to Livestock Production: Auckland.

Semakula, J., Lusembo, P., Kugonza, D. R., Mutetikka, D., Ssennyonjo, J., & Mwesigwa, M. (2011). Estimation of live body weight using zoometrical measurements for improved marketing of indigenous chicken in the Lake Victoria basin of Uganda. *Livestock Research for Rural Development*, *23*(8), Article 170. http://www.lrrd.org/lrrd23/8/sema23170.htm

Sseguya, H. & McMillan, D. E. (2015). Tracking progress and planning for the future. In M. L. Butler & D. E. McMillan, (Eds.), *Tapping philanthropy for development: Lessons learned from a public-private partnership in rural Uganda* (pp. 191–221). Kumarian.

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

Sumbule, E. K., Ambula, M. K., Osuga, I. M., Changeh, J. G., Mwangi, D. M., Subramanian, S., ... & Tanga, C. M. (2021). Cost-effectiveness of black soldier fly larvae meal as substitute of fishmeal in diets for layer chicks and growers. *Sustainability*, *13*(11), 6074. https://doi.org/10.3390/su13116074

Thorne, P., & Conroy, C. (2017). Research on livestock, livelihoods, and innovation. In S. Snapp & B. Pound. (Eds.), *Agricultural systems: Agroecology and rural innovation for development* (pp. 303–330). Academic Press.

Tusiime, S. M., Ozimati, A., Dramadri, I. O., Edema, R., Ahumuza, R., & Lukuyu, B. (2023). *Training report on production and quality assurance of forage seeds in Uganda*. Nairobi, Kenya: ILRI.

Twinamatsiko, R., Nalule, A. S., & Okello, S. (2020). Drivers and restrictions of range pasture improvement by agro-pastoralists in Kiruhura District, Uganda. *African Journal of Agricultural Research*, *16*(11), 1514–1530. https://doi.org/10.5897/AJAR2020.14959

Uganda Bureau of Statistics & International Classification of Functioning, Disability and Health. (2018). *Uganda demographic and health survey 2016. Key indicators report*. Kampala: Uganda.

Uganda Bureau of Statistics (UBOS). (2024). *National livestock census 2021 report*. Kampala: Uganda.

Van Tassell, C. P., Rosen, B. D., Woodward-Greene, M. J., Silverstein, J. T., Huson, H. J., Sölkner, J., ... & Sonstegard, T. S. (2023). The African Goat Improvement Network: A scientific group

empowering smallholder farmers. *Frontiers in Genetics*, *14*, 1183240. https://doi.org/10.3389/fgene.2023.1183240

Van Troos, K., Gomarasca, M., & Petit, H. (2018). *Community-based animal health workers (CAHWS) guardians for quality, localized animal health services in the global south*. VSF International.

Walugembe, M., Nadiope, G., Stock, J. D., Stalder, K. J., Pezo, D., & Rothschild, M. F. (2014). Prediction of live body weight using various body measurements in Ugandan village pigs. *Livestock Research for Rural Development, 26*(96). http://www.lrrd.org/lrrd26/5/walu26096.html

Yussif, I., Kugonza, D. R., Okot, M. W., Amuge, P. O., Costa, R., & Dos Anjos, F. (2023). Uganda chicken genetic resources: I. phenotypic and production characteristics. *Frontiers in Genetics*, *13*, 1033031. https://doi.org/10.3389/fgene.2022.1033031